WINTER CONSTRUCTION METHODS

WINTER CONSTRUCTION METHODS

PROCESSES AND PLANT EMPLOYED IN PROSECUTING CONSTRUCTION OPERATIONS IN COLD WEATHER

BY

CHARLES S. HILL

Associate Editor, Engineering News-Record

FIRST EDITION

McGRAW-HILL BOOK COMPANY, INC.
NEW YORK: 370 SEVENTH AVENUE
LONDON: 6 & 8 BOUVERIE ST.: E. C. 4
1928

PRINTED IN THE UNITED STATES OF AMERICA

THE MAPLE PRESS COMPANY, YORK, PA.

PREFACE

A technique of winter construction is being perfected. Practices have not been codified; much less have they been standardized. Constants and formulas for rational planning are widely lacking. With the experience available, however, constructors familiar with winter construction approach it with entire confidence and any constructor can gather the information which will warrant him in undertaking construction in cold weather. This volume is an effort to assemble this experience in such shape that it can be readily consulted and made use of. The need of such an undertaking is conspicuous.

Every season furnishes its examples of concrete failures due to ignorance of safe cold-weather construction practice. Only when these failures amount to structural disasters does the construction world take note of them. The countless occasions when only surface spalling, or the rupture or weakening of a detail are the result, go by with only the notice of the constructor who patches up the fault. Freezing is a real hazard in construction, and particularly in concrete construction. It may readily be guarded against, as the succeeding chapters describe; but it cannot be ignored and the book will have failed of its purpose if it does not drive home the conviction to every reader that the constructor assumes an extra risk when he undertakes winter concreting. Let him take the risk with confidence but with the proved defensive measures that experience furnishes him.

Since 1924, when the report of what is commonly known as the Hoover Committee on seasonal operation was made public, there has been increased interest in cutting down this item of industrial waste and an appreciable lengthening of the annual construction period has resulted. All-the-

year operation is an accepted doctrine of the construction business. Contractors' associations, building-trades employers' associations, associations of construction materials and equipment producers, individual contractors and manufacturers are all doing promotional work. Except that effort may not be slackened, this phase of the movement for winter construction may be accepted as formulated. The same progress has not been made in formulating a technique for winter construction. The call for such a labor is being voiced. In its report for 1926, the Committee on Construction Development of the Associated General Contractors said:

In the matter of winter construction, which the association has promoted consistently, it is noted that seasonal fluctuations in certain lines of construction are beginning to decline. It is believed important, however, to call attention to the fact that while winter operations have greatly increased, there has not been any extensive exchange of ideas on methods of winter construction. The pouring of concrete in extremely cold weather presents numerous dangers to those who are unfamiliar with proper methods. Failures are likely to occur, or the methods used, if safe, may be inefficient and costly. It is therefore suggested that the association give thought to methods of winter construction and establish contact with the engineering societies to develop the subject.

The committee has not exaggerated the importance of the task or the imminent need of its accomplishment. We believe this book makes a beginning. It lacks lamentably in constants and formulas for rational planning; in this respect it only reflects actual practice and emphasizes where fundamental data are wanted. It is, however, as said, a beginning. It also presents more complete information on the subject than is elsewhere available in one place. The sources of this information have been many. For the main sources it has been possible to give some credit in the text, but there are scores of others for which only blanket credit can be offered. Many of the operations have been

personally visited and observed. All the information is from authoritative sources. What does the round-up give us?

1. The knowledge that most kinds of construction can be carried on under the most severe winter conditions with means readily available to the contractor and with entire safety to the structure.

2. A summary of the principles and practices which have been successful in winter construction and which together constitute virtually a manual of practical methods and equipment.

3. A clear conception of the deficiencies in constants and formulas for rationally planning winter work and therefrom a plainly charted course for experiment and study.

C. S. H.

New York, N. Y.
September, 1928.

CONTENTS

WINTER CONSTRUCTION METHODS

CHAPTER I

ECONOMICS AND COST OF WINTER CONSTRUCTION

The economics and the cost of winter construction were thoroughly discussed in the Hoover Committee report of 1924. Although made four years ago this report in all its main contentions expresses the conditions as they exist today. Subsequent experience and records only confirm its arguments and substantiate its facts. This does not mean that there has not been progress. The public and the building industry are far better instructed in the theory and the facts of winter construction than they were four years ago and more winter work is being undertaken. With the Hoover Committee report available then, it is the purpose here only to indicate the economic arguments and to give general figures of cost.

1. Economic Advantages.—As the result of its study of winter construction the Hoover Committee found that:

1. Building materials can usually be obtained at somewhat reduced cost because of smaller demand.

2. Labor is generally more efficient because the labor supply is greater and the workman better appreciates the opportunity for work.

3. The owner may often save in interest on investment and gain in income, through earlier use of the structure.

Beyond these dollar and cents returns, which are facts and can be calculated, there is the larger economic gain of keeping the construction industry going as a whole. Winter construction decreases the annual period of idleness of construction labor, money, materials, and equipment.

2. Economic Disadvantages.—Against the economic advantages which have been cited there have to be counted the possibilities of inferior quality of construction, due to cold and exposure, and the certainty that cold and exposure add to the direct cost. In respect to quality, it need only be said here that the lesson of all that follows in this book is that nothing is needed but competence to produce a quality of work in winter equal to that obtained in summer. The question of cost will be considered more at length.

3. Definition of Winter Costs.—The first task in considering winter costs is to get a clear understanding of exactly what is meant by the term. It costs something always to guard against and combat cold and exposure in carrying on construction in winter. This may be termed *direct winter cost.* Yet the fact remains that construction in winter often costs no more, or but little more, and sometimes less, than in summer. The explanation of the seeming paradox is that the extra expenditure due to cold and exposure is counterbalanced by savings due to reduced materials prices, to the increased efficiency of labor, and to the fact that the contractor figures on a closer margin to keep his organization busy. As a specific example the following statement by John G. Ahlers[1] is given:

> The saving in cost of labor and materials, plus the anxiety of a contractor to keep his organization going through the winter, are reflected in two estimates that were made up some time ago on the same structure. Estimated to be built during the summer months, this building was figured to cost $208,000. The same structure was estimated to be built the following winter—as it did not go ahead in the summer—and, taking into consideration any change in the general trend of prices, it was figured to cost $203,000. Included in this price was the cost of protecting the structure during the severe cold months of the winter.

Winter costs then, as the term is used here, mean direct winter costs. Here is where actual figures are important and the discussion will be confined to them alone.

[1] Barney-Ahlers Construction Corporation.

4. Direct Winter Expenses.—With all other conditions the same, winter adds the cost of shelter, the cost of heating, and the cost of removing the obstacle of snow and ice to hauling and handling materials, and to safe movement about the work. These are direct winter expenses. They are not a constant; their ratio to total cost varies with every operation. Examples of actual costs are, therefore, indicative only.

Inquiry among Canadian general contractors develops a number of estimates which give an average of about 10 per cent as the extra cost of winter work. This figure is confirmed by an inquiry conducted by the Employment Service Council of Ontario. It is to be noted that the figure given is for general construction. There are reported instances where direct winter cost on large reinforced-concrete building operations ran as low as 3 per cent of the cost.

In the Hoover Committee report, Sanford E. Thompson gives perhaps the most extended record so far published of direct winter expenses of building construction. Table I is slightly changed from the tabulation in the report. Two factors are particularly to be observed: (1) The records are all of building construction on which direct winter expenses are less than on most other operations; and (2) the percentage of winter expenses, in general, decreases as the size of the operation increases.

On a $750,000 building built in New York in the winter of 1922–1923 by John Lowry, Jr., the direct winter expenses are given as follows:

Temporary protection: labor and materials			$ 871
Tarpaulins, Cost		$667	
	Salvage	442	225
Temporary heat:	Salamanders		268
	Coke		704
	Labor (salamanders)		302
	Boiler attendance, labor		1,036
	Coal, boiler heating		150
Temporary light, labor, and service			196
Snow clearing			111
			$3,863

The expense total is less than 0.5 per cent of the cost of the work.

On three medium-size building operations in Detroit, Mich., in the winter of 1923–1924, J. W. Robinson, of the Everett Winters Company, gives as direct winter expenses:

Item	1	2	3
Total cost	$355,000	$170,000	$85,000
Labor	1.4 per cent	1.2 per cent	
Materials, fuel, etc	1.6 per cent	0.7 per cent	
Total winter expense	3 per cent	1.9 per cent	4 per cent

On three typical reinforced-concrete building operations by the Barney-Ahlers Construction Corporation, William J. Barney finds direct winter expenses as follows:

Total cost	Time, protection	Cost, protection	Per cent
$263,000	December to January	$13,000	5
180,000	December to January	8,800	4½
95,000	January to February	6,300	6½

On a number of reinforced-concrete jobs running from $1,000,000 to $3,000,000, W. J. Lynch,[1] found the cost to run generally less than 1 per cent, and only in one case to be as much as 3 per cent. On steel-frame buildings, with concrete arches, the ratio is considerably less and on steel-frame buildings with tile arches, it is still less. The actual cost of protection on three different sizes of construction operations ranging from $95,000 to $263,000 is given by John G. Ahlers, of the Barney-Ahlers Construction Corporation, as from 4½ to 6½ per cent.

It needs to be emphasized again that these records are all of building construction using the progressive canvas housing method of protection. Other costs of building construction using complete wooden housing are given in Chap. XV. Figures of the cost of construction other than buildings are rare. Contractors estimate it at 10 to

[1] Thompson-Starrett Co.

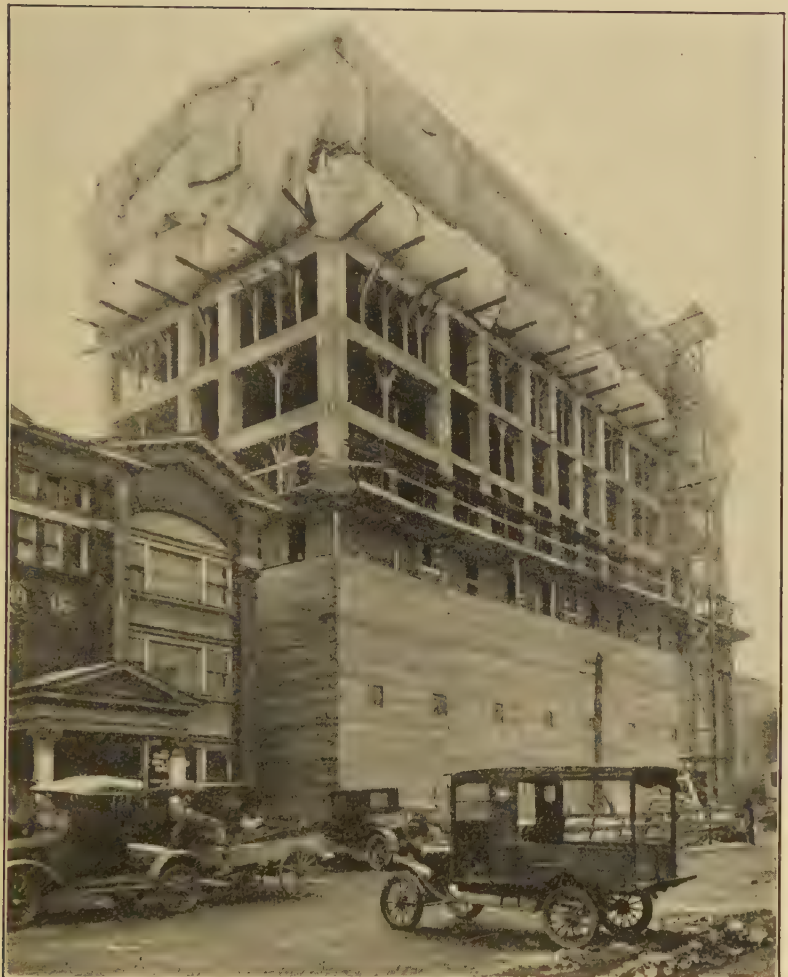


Plate I.—Housing employed on Piper Hotel building at Madison, Wis. Constructed in the winter of 1927 by the Henry W. Horst Company, Rock Island, Ill. Lowest temperature −30°; two floors kept curtained constantly; steam grill in basement heated aggregates dumped through sidewalk.

Table I.—Direct Winter-building Expense

From "Seasonal Construction and Unemployment"
(Hoover Committee Report)

Place	Approximate total cost of building*	Direct winter expense	Per cent of total cost
Quebec	$1,000,000	$25,735	2.57[1]
Massachusetts	1,100,000	40,327	3.67
Massachusetts	315,000	11,091	3.52
Massachusetts	375,000	24,776	6.61
Connecticut	150,000	6,015	4.01
Connecticut	250,000	7,153	2.86
Connecticut	450,000	19,365	4.30
Connecticut	2,000,000	42,550	2.13
Connecticut	165,000	3,160	1.92
Massachusetts	100,000*	5,800	5.80
Connecticut	245,000*	6,419	2.62
New York	425,000*	18,436	4.34
Massachusetts	90,000	2,500	2.78[2]
Maine	500,000	27,500	5.50[3]
New Jersey	2,100,000	48,300	2.30
New York	2,100,000	34,800	1.66
New Jersey	1,240,000	7,800	0.63
New York	745,000	31,200	4.19
New York	380,000	15,800	4.16
New Jersey	335,000	5,850	1.75
Island St. Pierre	320,000	4,080	1.27 [4]
New York	220,000	6,600	3.00
New York	175,000	4,880	2.79
New Jersey	135,000	3,768	2.79
New Jersey	83,500	3,350	4.01
New York	83,000	4,476	5.39
New York	53,000	3,350	6.32
New York	700,000	30,400	4.34
New York	180,000	5,090	2.83 [5]
New York	100,000	4,927	4.93
Average			3.50

* Reinforced concrete except three of brick as starred.

[1] Temperature 20° below zero while work in progress.

[2] Very heavy snow.

[3] Steam heating of space enclosed by canvas.

[4] Jobs of same contractor during severe winter of 1919–1920. (Two jobs done during mild winter of 1922–1923 averaged 75 per cent reduction in total labor item of the direct winter expense.)

[5] Estimated 10 cts. per square foot of floor area.

15 per cent, and 10 per cent may perhaps be taken as a fair figure for averaging winter costs.

5. Planning Approach.—In analyzing the economics of winter construction from the contractor's viewpoint, the important thing is to keep a clear distinction between direct winter expenses and construction costs as modified by lower prices and better labor markets, and then develop the proper planning approach. Primarily in winter construction there is need to develop a "winter complex." Cold weather produces certain conditions which warm weather does not. Whether summer conditions are more or less harmful or helpful is not the question. The winter conditions are different and are distinctly positive and characteristic. They have to be met by similarly different characteristic and positive winter construction planning. In brief, provisions for meeting winter conditions are not something to be grafted onto a construction plan. They must be contemplated in the premises and through every procedure of working out the plan. It is in this conception only that planning winter work emerges into the class of considered procedures of construction. There is nothing incidental in the effects of frost and snow on construction materials and servicing processes; they are in varying degrees substantial and ever-present influences in devising working plant and methods. They must be considered always in this aspect.

CHAPTER II

WINTER EFFICIENCY AND SERVICING OF LABOR

Labor is the critical factor in the practical problem of winter construction. With all his problems of materials and equipment, the constructor is primarily concerned with the question of not merely whether men can work but also whether they will work, how efficient they will be, what the accident hazards are, how they must be serviced on the job and, in case of necessity, in the construction camp. Men can work in winter, as will be shown, at practically all construction operations. How much and how efficiently they will work and the manner of safeguarding and servicing them depends on weather severity, vocation, and the prevalence of other less onerous means of employment. Let us examine the effect of these various factors.

6. Temperature and Weather.—It is not temperature alone, but weather, which determines ability and willingness to work in winter. Thermometer records concern the constructor chiefly when cold is accompanied by wind, sleet, or snow. Other things being equal, he will find it easier to get a full gang and a good day's work on a clear, calm, very cold day than on a warmer day with wind or snow. Eliminate the wind and precipitation factors and the constructor's cold-weather construction problem can be very closely appraised. There are, however, influencing degrees of temperature.

Tables II and III are abbreviated and assembled from several tabulations in the Hoover Committee report to exhibit: (1) influencing degrees of temperature; (2) geographical variations of influencing weather; (3) yearly variation of influencing weather, and (4) varying combinations of temperature and precipitation. No records are given of

wind. The figures make it very clear that weather influences on winter construction are variable in time and place. They are of slighter interest as giving specific values. For direct service, contractors require analyses of local weather records in much more detail.

7. Trades and Operations.—Weather has a varying influence on trades and operations. Considering the skilled trades—carpenters, masons, roofers and waterproofers, concrete finishers, lathers, plasterers, plumbers, electricians, etc.—it is roughly estimated by constructors that 50 per cent of their work is under shelter. This figure is based largely on experience in building construction where winter operations have made most progress and where shelter is comparatively easily secured. Steel workers are exposed. In other than building operations this is true also of form workers, masons and concrete workers. Machine operators, except drill runners, are sheltered. Common laborers generally work unsheltered.

Different operations afford differing degrees of shelter. Interior building operations are sheltered. Exterior wall masonry and steel erection are exposed, but the former can be readily sheltered. Partial shelter is afforded in trenching and in deep foundation work; artificial shelter is comparatively easy to provide. Tunnel excavation is fully sheltered and open-pit and cut excavation is exposed. Road construction, form work and framing, concreting, except building and subsurface work, hauling and handling materials, generally, are exposed operations. It will be evident then that the degree to which winter work can be prosecuted depends a great deal upon the relative percentages of favorable and unfavorable suboperations.

8. Storm and Frost Effects.—Only very broad generalizations are possible in appraising the effect of cold and storm on labor in construction. The possible combinations of temperature, wind, sleet, and snow are too numerous and the sensitiveness of different vocations to storm and frost is too variable to permit definite values to be laid down. In every case the contractor has to interpret effects in the light

of his particular operation and the local weather conditions. It is for this reason that he needs, as stated previously, local winter-weather records in detail. The following generalizations are based on temperature classifications in Tables II and III.

TABLE II.—COMPARATIVE WEATHER CONDITIONS FOR NINE CITIES

All Figures are 10-year Averages Expressed in Days
(Computation by Division of Building and Housing, Department of Commerce, from U. S. Weather Bureau Records)

City	Number of working days on which work was probably stopped by precipitation[1]				Number of working days, November to March, on which temperature fell below 32° F. between 7 A.M. and 6 P.M.				Total cold or rainy working days Nov. 1–Mar. 31[5]
	Apr. 1 to Oct. 31	Nov. 1 to March 31		Total days per year	Class I[2]	Class II[3]	Class III[4]	Total Classes I, II, and III	
		Occurring on warm days	Occurring on freezing days						
St. Paul	3.45	0.50	0.00	3.95	58.6	19.9	27.4	105.9	106.40
Denver	1.90	0.10	0.65	2.65	24.7	21.8	37.1	83.6	83.70
Chicago	4.60	2.05	0.85	7.50	24.2	16.6	31.4	72.2	74.25
Boston	6.45	2.90	3.30	12.65	20.3	19.7	31.7	71.7	74.60
New York	5.60	3.60	3.90	13.10	14.3	16.2	33.4	63.9	67.50
St. Louis	5.75	3.50	1.85	11.10	14.9	12.0	29.3	56.2	59.70
Atlanta	6.35	5.35	0.15	11.85	1.7	4.9	15.4	22.0	27.35
New Orleans	4.95	4.70	0.00	9.65	0.0	0.2	1.7	1.9	6.60
San Francisco	0.80	5.40	0.00	6.20	0.0	0.0	0.0	0.0	5.40

[1] Precipitation: Rain, snow, or sleet of 0.05 in. and over per hour (water content).

[2] Class I (colder days): Days on which temperature fell below 18° at some time, or did not rise above 24° at any time.

[3] Class II (medium days): Lowest not below 18° but temperature reached or exceeded 23° during the day.

[4] Class III (warmer days): Lowest between 25° and 32°.

[5] Total cold or rainy working days: November 1 to March 31. Sum of days in column 2 and column 8. The term "working days" includes all except Sundays and holidays.

It has been said that storm, with cold, has far greater influence on labor than does cold alone. In respect to temperature, the Hoover Committee concludes that the efficiency of most work on outdoor jobs is not much affected by days of Class III, in which the temperature at any time during the working day does not go below 25°. The second class of cold days, which is relatively small, will begin to interfere with the efficiency of work in exposed

TABLE III.—WEATHER CONDITIONS AFFECTING OUTDOOR CONSTRUCTION, NEW YORK, N. Y., 1913–1923

Number of Working Days on Which Temperature Fell below 32° F. between 7 A.M. and 6 P.M.

(Computation by Division of Building and Housing, Department of Commerce, from U. S. Weather Bureau Records)

Winter	Class I days[1]	Class II days[2]	Class III days[3]	Total cold days	Wet days
1913–1914	17	14	32	63	10.5
1914–1915	7	18	42	67	14.0
1915–1916	17	18	42	77	15.0
1916–1917	13	21	28	62	19.0
1917–1918	26	25	25	76	11.0
1918–1919	4	9	32	45	12.0
1919–1920	23	17	40	80	18.5
1920–1921	7	6	29	42	10.0
1921–1922	12	13	37	62	14.0
1922–1923	17	21	27	65	7.5
Average	14.3	16.2	33.4	63.9	13.1

[1] Class I (colder days): Days on which temperature fell below 18° at some time, or did not rise above 24° at any time.

[2] Class II (medium days): Lowest not below 18° but temperature reached or exceeded 25° during the day.

[3] Class III (warmer days): Lowest between 25° and 32°

places, particularly if there is a wind, though a day in which the early morning temperature is around 20 to 24° may turn out to be very mild. Most of Class I days interfere, to a certain extent, with outside work, although heavy timber and bridgework, mass concrete below grade, certain kinds of excavation, piling, and other jobs can be carried on with reasonable efficiency.

These are reasonable conclusions considering temperature alone. Practically, the degree of interference of cold of various intensities is largely modified by special equipment and processes and experienced management. As an example, regard the number of cold days in New York in 10 years as given in Tables II and III. Statistics of actual lost time for virtually the same period by the Geo. A. Fuller Company, building contractors, show that on only 14 days each year was construction practically impossible due to

temperature. Commenting on this figure J. Reid Kilpatrick, vice-president, said:

> It is necessary to consider figures for rather extended periods because one job, or two jobs, or three jobs running one, or two, or three years give a result which might mislead one in appraising general conditions. The periods in the 10 years, for which work was interrupted, run 5 to 31 days a year.

While the facts as given of climatic influences on construction trades and operations are perhaps only such as could be inferred, they have been mentioned thus at length to emphasize the very important truths that:

1. There is no general winter-construction condition; instead every operation has its individual winter-construction conditions determined by the reactions between several factors.

2. Weather interference with construction in winter is modified by the availability of special equipment, processes, structural types, construction materials, and protective measures.

3. Successful winter-construction technique involves scheduling job operations and coordinating extra-job services so as to minimize on the operation as a whole the handicapping effect of weather on any individual craft.

9. Winter Labor Efficiency.—Extremes of temperature and storm affect the efficiency of labor. The degree varies with the severity of the weather and with the operation, as has been stated, but, in general, all manual operations are less deft, tools and materials are less tractable in manipulation, footing is slippery, the men are bundled up and hear, see, and move less quickly. Considering the labor force as a whole, efficiency is decreased in another manner—full gangs are more difficult to maintain. The sting of frost, sleet, and wind, and the fear of illness from cold and wet influence men to stay at home on bad days and to hunt the occasional jobs which give shelter and warmth. With all this truth of fact and logic of argument, however, records of winter construction confront us with the fact that labor

Plate II.—Baskatong storage dam in Northern Quebec.

Constructed in the winter of 1927 by the Foundation Company of Canada, Ltd., Montreal, Quebec, using heated concrete and steam-heated canvas covering over tops of forms.

productivity is greater in winter and labor costs are less per unit of construction. Let us consider first the records.

Direct comparison in units of output between winter and summer labor is very nearly impossible. Records are lacking. In a talk before the New York Building Congress, John Lowry, Jr., building contractor, referring to a specific $750,000 building operation, said:

> Taking as a base the production per day of a bricklayer in the summer of 1922 at 100 per cent, it was found from actual figures that the production in the winter of 1922–1923 was 109½ per cent; that is, the bricklayers laid 9½ per cent more brick in the winter than in the previous summer, on a similar job. In the summer of 1923 when bricklayers were scarcer than in 1922, production dropped to 91 per cent of the 1922 figures.

Estimates by constructors of the relative output of labor in winter range from minus 15 per cent to plus 15 per cent and are so erratic, and in some cases so manifestly mere guesses, that they are of no value.

On the basis of labor unit costs, the records are available for somewhat more complete comparison. In the report of the Hoover Committee, Sanford E. Thompson gives four tables comparing labor unit costs in summer and in winter. A summary of the percentages of saving in brick masonry, in the cases cited, shows an average of about 15 per cent decrease in the winter labor costs from standard. There is a somewhat less saving in reinforcing labor, about 6 per cent, and in concrete labor, about 11 per cent. Form labor is apt to cost slightly more, about 8 per cent, in winter.

Explanation of this commonly greater productiveness in the bad-weather season of the year is given by practically all who offer the evidence as follows:

1. In the winter, owing to the general slacking down of construction, there is a surplus of workmen, while in the summer, with construction at its seasonal peak, there is a shortage.

2. Because of winter idleness, the common labor wage scale is less and skilled labor can be had at union wages, whereas in summer a bonus commonly has to be paid.

3. Because of lack of employment in winter all workmen, to hold their jobs, work harder and faster.

This explanation demands closer consideration. It reduces in plain words to the following generalization: The physical conditions of winter work are more difficult but employment conditions are so much more favorable in winter that they overcome the handicap of cold weather. Then it follows:

1. As the practice of winter construction grows toward a full 12-month construction year, the employment curve will approximate a level line instead of showing the present summer peak and winter valley. Coordinately, the wage curve will straighten out at a level below the present summer peak but also well above the present winter valley. Correspondingly, the labor efficiency curve will lose its present winter peak but probably also will rise above its present summer valley. Therefore, the constructor cannot expect a continuation, as winter construction increases, of the slump in wages and the jump in efficiency which now enable him to show lower labor costs on winter operations.

2. The surplus of labor under present conditions, even in the cold-winter zones, is not uniform over the country. The Hoover Committee report indicates this condition clearly. (1) In certain cities and regions, winter construction has already become common and the wages and efficiency curves are straightening out locally. (2) In other localities, opportunity to get other work in winter is offered construction laborers and there is no intensive unemployment. Under these conditions the constructor must take an individual view of winter construction. Construction, with him, is not a generalization. It is always a specific local problem. In the locality and for the particular operation he may, or he may not, be in a position to get increased labor productivity in winter. He must plan and estimate according to the conditions, not according to national graphs of labor supply and weather conditions.

10. Winter Labor Hazards.—Legislation and custom today make the contractor the guardian of the safety of his workmen. He is financially responsible for accidents. Hazard, therefore, is a liability and must be appraised according to the conditions. Frost and storm increase hazard. How much? Here again we are confronted with lack of data and diversity of opinion. We have then to fall back on general reasoning.

Snow and ice make slippery footing. Tools are cold and slippery. Explosives have to be thawed. Wind and snow reduce vision and drown other sounds. The men are bundled up and are less quick to see, hear, and get out of the way of trains and other moving loads. Canadian contractors assert that there is greater breakage of tools, wire rope, and derrick parts. All these conditions increase the theoretical hazard of winter work. On the other hand, keen consciousness by the workmen of this hazard may increase caution or the contractor may employ extra safety measures which may overcome the extra hazard. The point to be observed is that all these things are factors for consideration in the contractor's problem of winter construction.

11. Combating Exposure.—In respect to labor, it follows, from what has been said, that combating exposure is the essential winter task of the constructor. Exposure, as understood by him, has a significance beyond the dictionary definition. It is a function of locality, of kind of equipment, of nature of operation, and of structural form, all regardless of general climate. It is one thing on an open plain and another in a sheltered valley. It is one thing when housed in a steam-shovel cab and another when riding a tractor. It is one thing in driving a tunnel and another in erecting a standpipe. Emphasis has been put on these obvious facts because it is important to understand that exposure, the most influencing factor in winter construction is, as the constructor must regard it, a specific, individually definite condition and not a climatic generalization.

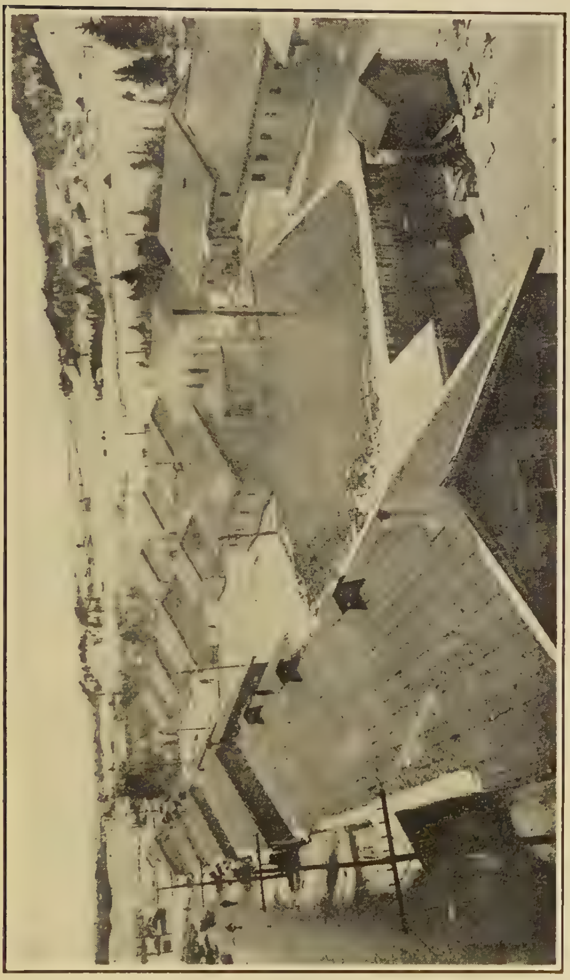


FIG. 1.—Winter construction camp on a Canadian hydroelectric job.

This camp was built by the Fraser-Brace Engineering Company on a hydro-electric operation at Chelsae on the Gatineau River about seven miles north of Ottawa, Ontario. Note the orderly arrangement of the buildings, their substantial construction, the provisions for lighting and ventilation and the pipe chimneys indicating the provisions for heating.

Combating exposure is the specific task of winter construction. In respect to labor, it involves general camp servicing, job servicing, heating, and fire protection.

12. Camp Servicing of Labor.—Extra camp service is required in winter. There has to be heat and particularly there has to be warmth and plenty of hot water for bathing and clothes washing. If these duties are not made comfortable, they will be neglected and personal hygiene will suffer with increased danger of infection to cuts and punctures

Fig. 2.—Winter construction camp, Gulf Island Dam, Maine (Morton C. Tuttle Company, Boston, Mass., contractors).

and a lower resistance to diseases. Lighting, too, has to be better. There is more darkness in winter, the men are in the house more, as they take their recreation inside. And here, let it be noted, more facilities for recreation are desirable. Irritableness develops rapidly where men are cooped in without means of diversion. The construction camp is often a pretty bleak place (Figs. 1 and 2). A recreation hall, a motion-picture projector, and a radio outfit are very profitable pieces of equipment for any winter-construction camp.

Hygiene and sanitation have been spoken of; they should extend into the housekeeping particularly. Ventilation and airing have to be better looked after in winter; the men

who open their windows for comfort in summer will in winter close them for the same purpose. Plenty of blankets (Fig. 3) will help much in keeping a well-aired bunk house

Fig 3.—Interior of a winter bunkhouse showing two-man bunks.
Note the metal bunks, the plentiful supply of blankets, the lighting, the ample air space and the division by partitions. There is no elaboration of structure but every provision for comfort and health.

Fig. 4.—Bunkhouses in winter on a Maine hydroelectric job.

in winter (Fig. 4). Water supply is all-important, and also calls for more cold-weather precautions than any other camp servicing.

Winter conditions provide somewhat different kinds of camp hospital cases than do summer conditions, but the service required is not especially more exacting or difficult.

In particular, however, general sanitation cannot be slacked off in winter. The fact that frost seals up the offensiveness of filth and decay may permit of some delay in, but does not lessen the necessity of, the sanitary disposal of garbage, sewage, and other wastes.

13. Job Servicing of Labor.—Besides the camp servicing of workmen, which has been indicated, there has to be in winter extra, or different, job servicing. The larger portion of this has to do with providing safe accessibility to working operations about the job, and this is developed in Sec. 31. Another portion is job shelter.

Camp housing is not the only shelter which winter conditions make desirable. Workmen can be protected in many operations by huts or windbreaks, and the protection usually pays a profit of greater efficiency. It is not meant that every man shall lug about an oil stove and a pup tent; common sense must be exercised. But the writer has seen jack-hammer drill men working in small portable cone-shaped cove tents and a group of shovelers in the lee of a canvas windbreak, and footage and yardage were added to the day's performance as a consequence. Open fires, or better, a lean-to, and stove where the men can go occasionally to warm their hands, will help keep labor on the job. In speaking of labor efficiency in cold weather, A. M. Bouillon, with experience on many winter operations, says:

On quiet days with temperatures not lower than about 5° below zero, the average production output per man on outside work is not decreased, but is practically at its highest, the same as in the cool days following the first frost of the late fall, for the men are active and work steadily, the slight nip of the cold proving an incentive to exercise, so that they unconsciously accomplish more than the usual summer average. However, when the weather is so cold as to compel men to hamper their movements with heavy clothes, such as happens when the temperature reaches about 20° below zero, and also *when there is a wind at any*

temperature below freezing, there is a perceptible slackening in the work of the men in exposed places, but this does not affect men working under shelter.

Practices in the larger tasks of job shelter are described in the succeeding chapters; they have been carefully and quite adequately developed. It is the minor opportunities for shelter and particularly portable shelter which are in mind here and which have been neglected.

CHAPTER III

WATER SUPPLY, FIRE PROTECTION, AND CAMP HEATING

In connection with the camp and job servicing of labor in winter, water supply, fire protection, and heating call for especial consideration. The first two services are as much required in summer as in winter but frost introduces factors into the problem which do not exist in warm weather. Heating is specifically a cold-weather requirement.

14. Water Supply.—In cities or towns or anywhere adjacent to established waterworks, water supply for construction is simple. Generally, the future operation of the structure being built calls for water service and the permanent connections will be made at once. Then the construction supply requires merely such temporary job pipe and hose lines as the conditions may require. Their cold-weather protection is the same as is described here for isolated construction-camp and job service and in Sec. 34 for servicing equipment on the job. On isolated operations, camp and job water supply becomes a special problem.

Where construction is isolated, a waterworks, consisting of pumps, mains, hydrants, and services, has to be built. It usually must supply water for drinking and cooking as well as for sanitation and construction and as the source is usually a local stream or lake, chlorination is required in most cases. With electric power available, two pumps should be installed, one a two-stage centrifugal electrically driven, and the other a duplex pump operated by compressed air or steam. There may be other choices than these but the point made is that an auxiliary or standby pump should be a part of the installation. The chlorinator should be connected to both pumps and installed in a small room in the pump house.

For construction-camp service, standard black wrought-iron pipe is generally used—6-in. and 4-in. mains with screwed or flanged connections. To prevent freezing, (1) the pipe is buried in trench in the ground or (2) laid overground and boxed in or provided with other insulation. Obviously, with construction operations of rarely greater duration than two winters, trenching for water pipes is economic only where it can be easily done. It is warranted only in soft earth; for hard ground and rock the better solution is overground lines and protection.

Two methods of overground water-pipe protection are shown by Fig. 5. Both were employed on power-plant and dam construction operations in Canada. North of Ottawa

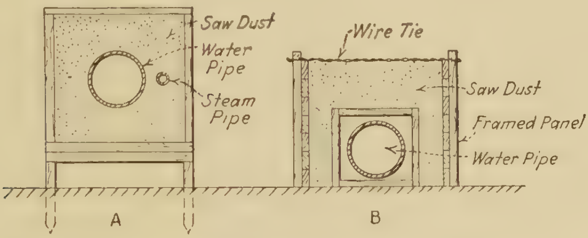


Fig. 5.—Examples of overground water-pipe protection.

about 140 miles, on dam work in Quebec, about 2 miles of camp water main on low timber bents were boxed in and heated as shown by sketch *A*, Fig. 5.[1] On power-plant work on the Gatineau River near Ottawa, the pipe, sketch *B*, Fig. 5, was laid on the ground in a box slightly larger than the pipe. Wooden panels were then wired up on each side of the box and the space between them was filled with sawdust.[2] These lines gave no trouble from freezing.

15. Fire Protection.—Fire protection of construction work is closely related to water supply. In general, in winter there is less danger from spreading leaf and brush fires and all litter, lumber, stock, falseworks, and forms are less inflammable than in summer. There are, however, in

[1] Foundation Company, of Canada, Ltd.

[2] Fraser-Brace Engineering Company, Ltd.

materials-heating furnaces, boiler fires, salamanders, and stoves, more foci for the start of flame. The men, too, will build open fires for hand warming and other personal uses. Fire protection is a dual task of preventing fire and of fighting fire.

Fire prevention is not a problem of special installation so much as it is the development of constant watchfulness and meticulous procedure in reducing fire hazards. These are no different for winter work than for summer work—the points to be guarded are merely greater in number in winter. As an example, in building work one of the fire hazards is canvas inclosures heated by salamanders. Canvas is inflammable and waterproofed canvas is particularly so. There appears to have been little success in fireproofing canvas. Most fireproofing application is easily soluble in water and exposure of covers and curtains to the weather soon puts any fireproofing out of commission. Again it causes mildew and rapid deterioration of the cloth. The best fire protection of canvas enclosure is to see that the curtains and covers are so well lashed that they cannot fall or flap into the salamander fires. Then provide handy water barrels and buckets and at night *have a good watchman on the job.* So with construction of all kinds, not much can be done in any fireproofing way. What has to be done is to keep fire from catching—cut down the places where open fire and flame are used; keep inflammable materials out of catching distance from open fire and flame; keep up a constant round of inspection by watchmen to detect the start of fire; train workmen to habits, in smoking and in using fire, of carefulness to prevent the start of fire. The first rule in brief, in construction, for protection is, first, prevent fire, last fight fire.

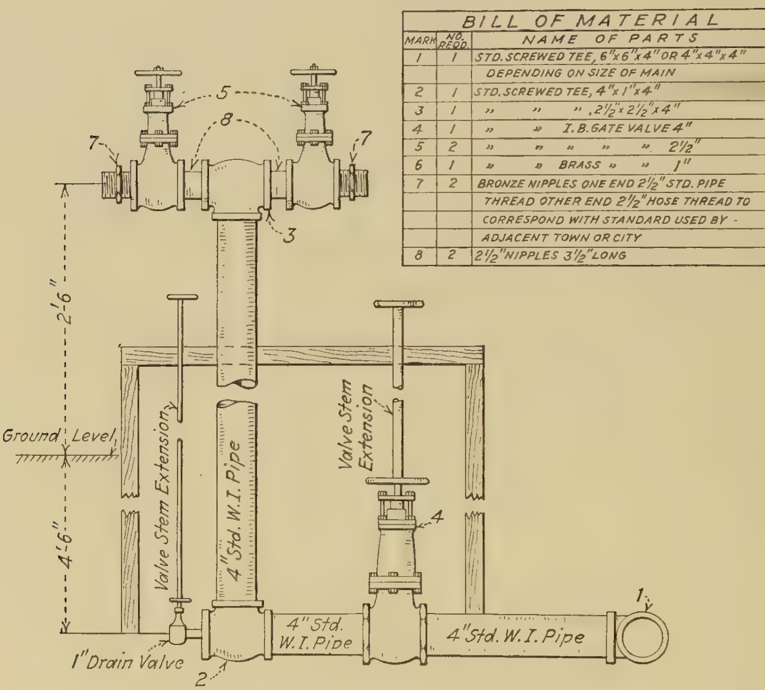
Winter puts a handicap on the ordinary means of fighting fire. Pipe lines freeze and water in barrels and pails becomes ice unless all are guarded against frost. On power-plant work in Quebec, in 1926, the following means were provided for fighting camp and job fires: The water mains were laid in trench or overground with the protec-

PLATE III.—Dam at Kells, Mich., constructed in winter of 1926–1927.

Concrege aggregates and water preheated and heated again in mixer with torch heater; hot concrete chuted to canvas-covered forms heated by salamanders. Siems, Helmers and Schaffner, St. Paul, Minn., contractors.

tion indicated by sketch *B*, Fig. 5. At each of two operations about 25 hydrants were provided for fire fighting.

The hydrants were made up on the job from standard blackpipe, and fittings, as shown by Fig. 6. A box of 2-in. plank about 3 ft. 6 in. square was built around each hydrant with a small box just large enough to enclose the valves



BILL OF MATERIAL		
MARK	NO. REQD.	NAME OF PARTS
1	1	STD. SCREWED TEE, 6"x6"x4" OR 4"x4"x4"
		DEPENDING ON SIZE OF MAIN
2	1	STD. SCREWED TEE, 4"x1"x4"
3	1	" " " ,2½"x2½"x4"
4	1	" " I.B. GATE VALVE 4"
5	2	" " " " " 2½"
6	1	" " BRASS " " 1"
7	2	BRONZE NIPPLES ONE END 2½" STD. PIPE
		THREAD OTHER END 2½" HOSE THREAD TO
		CORRESPOND WITH STANDARD USED BY -
		ADJACENT TOWN OR CITY
8	2	2½" NIPPLES 3½" LONG

Fig. 6.—Hydrant for camp and job fire protection.

inside of it. This inside box had a loose cover, and the valve spindles were brought up through it. The space between the two boxes and over the top was then filled with manure or sawdust to the top of the outer box, or about 1 ft. above the ground. Very little trouble was experienced due to these hydrants freezing.

Fire stations were established at central points about the job. These stations were built over a hydrant, and consisted of a building about 6 ft. square, with double doors on

the front. They were each equipped with 200 ft. of 2½-in. standard fire underwriters hose, two 30-in. play pipes, hose wrenches, axes, lanterns, and pails. Outside of each fire station, a rack was built which carried two ladders of suitable lengths to reach roofs in the immediate vicinity. In addition to the above equipment, a reel house was built. This contained a hose reel equipped with 200 ft. of hose, nozzles, wrenches, lanterns, and axes.

Two fire brigades were appointed and drilled in the use of the equipment, and when a night shift was working, a third brigade was appointed for night duty. Each brigade consisted of a captain and four or five men. A fire inspector was also appointed, whose duty it was to inspect regularly the hydrants and equipment and also to report any inflammable material, such as oily waste, scrap wood, etc., which might be left around.[1]

16. Construction-camp Heating.—In practice, construction-camp buildings are heated usually by stoves and exceptionally by central heating plants. Few construction operations last through more than two winters and with no longer period of service the installation of a central heating plant is not economy. Its cost is too great. Good insulation of steam lines is expensive and ordinarily, under the conditions that prevail, the heat losses are high. As an indication of practice, examples of both stove and central-plant heating are given.

17. Heating with Stoves.—The practice of a construction company which carries on much winter work in Canada where the camps are isolated and commonly in wooded regions is as follows: Practice has standardized on box stoves using 2-ft. wood, two of these stoves being installed in a 44-man bunk house. These bunk houses are partitioned in the center and one stove is installed in the center of each section. A night man is kept in attendance and he can handle the firing for 12 to 15 bunk houses. The average fuel consumption is one-fourth cord of 2-ft. wood per stove per day. This is for average Canadian

[1] Fraser-Brace Engineering Company, Ltd.

winter weather. Costs are rather difficult to arrive at due to varying cost of wood production and varying quality of wood. Firewood averages about $3 a cord of average quality of 2-ft. wood delivered at camp. The cost of heating

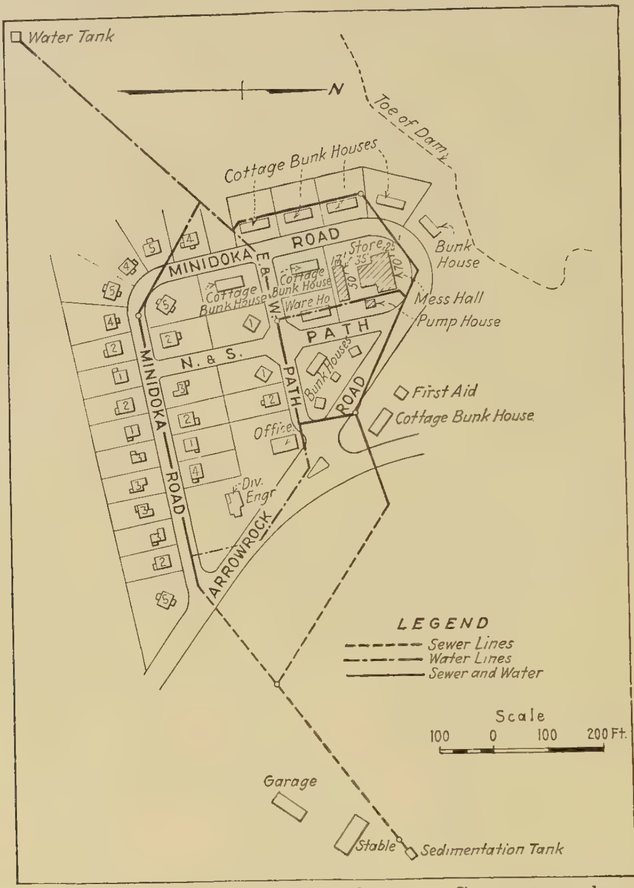


FIG. 7.—Central heating and camp layout at Germantown dam.

one bunk house, then, prorating the night foreman's time, will average $1.80 a day.

For a 200- to 250-man mess hall, two 36-in. box stoves are set about one-fourth the length of the building from each end. These stoves will burn either 2- or 3-ft. wood and the cost of operating them is about the same as given for a bunk house.

In camps at rail head, where coal is more economical than wood, Quebec heaters are installed; these are much superior to wood stoves. Occasionally steam heat furnished by a boiler outside the building has been provided for a job office and warehouse in one building. This is not an economical installation.[1]

18. Central Heating Plants.—In building the flood protection dams of the Miami Conservancy District in Ohio, central heating was installed for some of the buildings at two camps. Figure 7 shows the camp at the Germantown

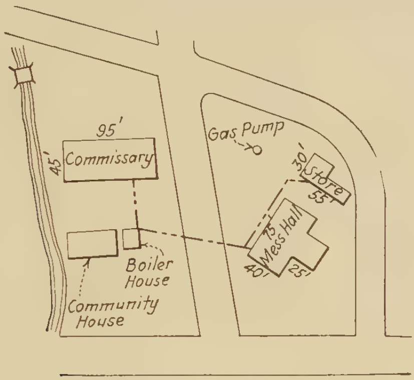


Fig. 8 —Central heating and camp layout at Taylorsville dam.

dam in which the centrally heated buildings are indicated by cross-hatching. Incidentally, this is an excellent example of camp layout and servicing; it accommodated 300 people and provided electric light, sewerage, and water for every building. Water mains and sewers were permanently laid in trenches. For the centrally heated mess hall and store, steam was supplied by a 15-hp., horizontal 42 × 120 in. boiler located in the pump house where it also furnished steam for a pump pumping to an elevated water tank. All other camp buildings were heated by standard coal-heating stoves, with side-door feed and 16- to 18-in. bowls. At Taylorsville dam the store, mess hall and commissary, located as shown by Fig. 8, were heated by a boiler of the same size and type used at Germantown dam.

[1] Foundation Company of Canada, Ltd.

CHAPTER IV

CONSTRUCTION ELEMENTS AFFECTING WINTER WORK

In a generation the art of construction has improved beyond the measure and recognition of the general public. This improvement exists in structural types, in equipment, processes, materials, and protective measures. Today the contractor is a more confident winter builder because of these advances in the art of construction. This influence on the economics of winter construction was given prominent consideration in the Hoover Committee report and is discussed here only as it concerns the practical constructor.

19. Structural Types.—Steel framework and reinforced concrete are the outstanding structural-type developments of modern practice. Both have contributed to the possibilities of cold-weather work but in different ways. Concrete as it goes into the structure and gains structural integrity is not a good winter-construction material. Fundamental and adaptable methods and readily applicable protective measures make it a practicable winter material. On the contrary, in its nature and in the form in which it is produced and put up, steel framework is a notably perfect material for cold weather. It is the primary structural-type development which has increased the contractor's ability to build in winter.

Steel framework is directly serviceable to the contractor for winter operations for the reason that it comes to the work in fabricated units which have only to be assembled on the job and then are immediately of full structural strength. This immediate structural integrity gives in high perfection the indirect winter-construction advantage of support for scaffolds, temporary shelters, or permanent walls and floors. These direct and indirect qualifications of steel framework

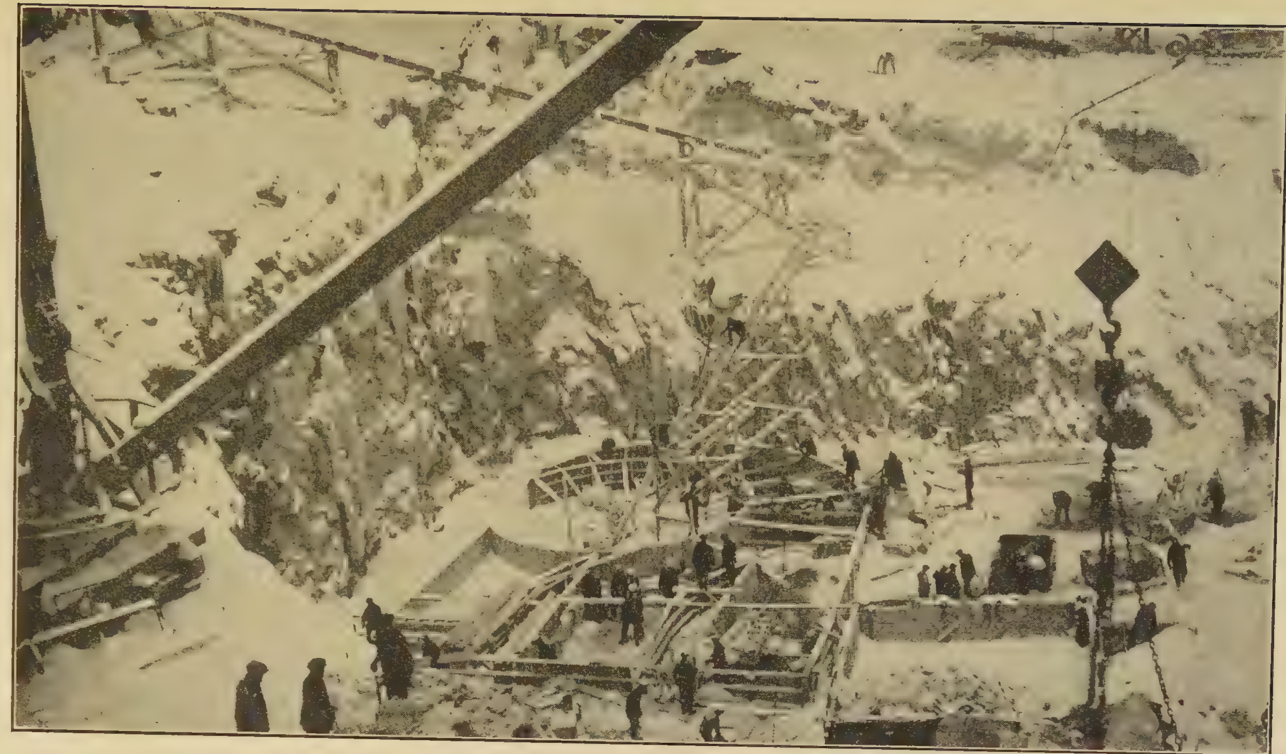


Plate IV.—Power house for hydroelectric plant at Chelsae; Gatineau River, Quebec. Getting chute lines and forms ready for concreting first waterwheel emplacement in March, 1926. Fraser-Brace Engineering Company, Ltd., Montreal, Quebec.

for winter construction are demonstrated in the common practice of building steel-frame buildings, steel bridges, or any other steel structure in winter.

The general confidence of contractors in the practicability of structural steelwork in winter is indicated in the statement of J. Reid Kilpatrick, of the George W. Fuller Company, that:

In structural-steel work there is no particular winter problem. The work may be interrupted by snowstorms but the quantity of work a man does is not restricted by temperature. The opinion has existed that steelwork in winter is particularly hazardous on account of the ice and snow. I have investigated this and found that there is really no difference.

Turning to other structural types in their relation to ease of winter construction, it is observed that such advance as is shown comes from improved materials or methods. This is true even of reinforced concrete which, next to steel framework, is the most important modern structural-type development. In brick and stone masonry any advance in ease and certainty of winter work is due to methods, tools, materials, or protective measures.

20. Equipment.—In no respect, perhaps, has the contractor been so much aided in his ability to work in winter as by wide invention and improvement in construction equipment. Let us look at a single illustration. Without the modern highly improved hoisting machine and the pneumatic hammer, steel framework would have fallen considerably short of its present possibilities of being successfully prosecuted in winter.

It is practicable to consider only broad phases in equipment development as it has affected winter work. Machines and even types of machines are too numerous to be considered individually. The phases are (1) size and power, (2) mobility, (3) mechanical perfection, and (4) special-purpose machine invention. Increase in size and power aids the winter builder in a number of ways:

1. Larger shop-fabricated units can be handled, as in steel erection and form construction, thus reducing manual operations in the field.

2. In concrete work larger containers, buckets, and cars conserve the temperature of heated concrete.

3. In excavation the heavier shovels readily dig frozen ground and with motor trucks, larger cars, and more powerful derricks, the frozen earth and rock can be loaded and hauled in larger pieces and so reduce secondary reduction in pit and quarry.

In the matter of power, advantage comes, as indicated, from larger units and, in addition, from the extension of the choice of power unit to gas engines and electric motors. Compared with steam engines, either unit cuts down haulage at the time when job roads are at their worst and reduces the number of men serving fuel to equipment.

Independence of winter road conditions is increased by tractor-hauled and tractor-mounted equipment and industrial railways. In particular, the crawler traction for both tractors and tractor mounts has materially reduced the winter obstacles which snow, ice, and mud offer to shifting machines and moving loads. Summed up, the present high development in variety, power, mobility, and mechanical perfection of construction equipment reduces the necessary human element in winter construction.

21. Materials and Millwork.—There has been a material gain to winter construction in new forms of manufactured products of various materials as precast concrete units, wall and floor tile, partition blocks, mill-fabricated wood and metal building units, and plaster board. In laying stone, brick, and tile, portland cement gives a quicker high-strength mortar and the new alumina cements and super-portlands offer possibilities along this line which have not yet been fully developed. The cutting to length and size and even mill framing of lumber reduces fieldwork. Mill-cut and bent reinforcing steel is another help.

CHAPTER V

TRANSPORTING AND STORING MATERIALS IN WINTER

Materials, supplies, and certain hauling processes are common to all construction. The effect of cold on them is, then, of first consideration in winter work. This effect is various, depending upon the nature of the material or process, upon snowfall and storm, and in particular upon the moisture conditions. Cold makes virtually all materials and supplies more intractable to use, it makes some impossible of use until frost is removed, and it prevents the proper functioning of and may do integral damage to others. Some hauling processes are hindered by cold and for others frost and snow may actually improve conditions. It is, therefore, impracticable to lay down any universal rule of winter procedure. This necessitates separate consideration of each material or process or of each class of similar materials or processes; in brief, a separate winter-construction plan for each operation. This is the first axiom of successful construction in cold weather.

22. Storing Construction Materials.—Ice formation is about the only damaging effect of cold on the major construction materials except concrete. Also, their resistance, except concrete, to ice formation is virtually nil. Contained or entrapped water by freezing may affect the usability of brick, tile, stone, steel, timber, crushed rock, sand, and gravel, and, to some extent, on some of them may act disruptively, but ordinarily it does no damage which is not repaired by thawing. Concrete offers a positive resistance to frost action and suffers at least delayed attainment of strength and maybe permanent structural injury by freezing. Its consideration as a winter building material is paramount, and is extended in Chaps. XI to XVI.

Winter handling and care of construction materials ordinarily does not contemplate shelter. Their bulk makes inclosed storage expensive and as generally ice formation does them no hurt it is cheaper to store them unsheltered and thaw the ice away as they are requisitioned for use. This does not mean that careless location of stock piles where snow and ice can accumulate is permissible. Indeed, every reasonable care should be taken to choose dry and sheltered storage places. Cement is the exception; cold does it no harm, but it must be housed against moisture, and for this the requirements are no different for winter than for any other time. Except cement, then, winter handling of construction materials involves no task due to cold except the process (generally thawing) of preparing them for use.

To reduce the labor of thawing, some contractors provide shelter for such materials as brick, tile, and reinforcing steel. Ordinarily, this shelter consists of no more than a cover or roof to keep off snow and sleet and of providing a floor raised off the ground enough to be out of the wet and mud. Generally this latter provision should be made in piling timber, steel beams, and other materials which otherwise will freeze to the ground. The extent of shelter justified depends on the conditions of delivery; the ground conditions whether wet or dry; the character of the storms whether rain and sleet or dry snow fall, and the character and purpose of the material. In general, all supplies such as bolts, nails and all small metal parts, and of course all supplies injured by frost or wet, should be housed.

23. Lubricants.—Special lubricants and special handling of lubricants are required for cold-weather equipment operations. Neglecting technicalities and fine qualifications, the suitability of a lubricant for cold-weather use is determined by (1) its viscosity and (2) its pour point at which the oil will pour or flow when chilled. Not only must oils and greases be of such characteristics as to be readily handled, but also they must be capable of flowing to the innermost surfaces of the wearing elements under the

action of gravity or the available pressure. Simply because it may be practicable to handle such lubricants in a steam-heated building, it must not be neglected to investigate their viscosity and pour point at zero or under whatever probable outdoor temperature they may be used. In general, however, the practical constructor had better call in the lubricating expert when it comes to specifying and testing cold-weather oils. Table IV gives the characteristics of lubricants for cold weather advised by A. F. Brewer, mechanical engineer of the Texas Company.

Table IV.—Lubricants Recommended for Construction Machinery

Part to be lubricated	Viscosity, seconds Saybolt		Pour-test range for winter service
	Summer	Winter	
Gears—exposed or merely guarded	2,000 at 210°	1,000 at 210°	
Gears—enclosed, where bath lubrication is possible	1,000 at 210°	115 to 200 at 210°	15° F. or lower
Wire rope	1,000 at 210°	500 to 600 at 210°	
Chains—roller type usually exposed	1,000 at 210°	500 to 600 at 210°	
Chains—silent or link type			
Exposed	115 to 120 at 210°	70 to 80 at 210°	10° F. or lower
Enclosed	70 to 80 at 210°	55 to 60 at 210°	0° F. if possible
Steam cylinders	130 to 150 at 210°	120 to 130 at 210°	As low as possible
Link pins and rollers of caterpillar tractors	200 at 210°	115 at 210°	15° F or lower
Internal combustion engines.	See recommendations of builders and oil companies, according to type and size of engines and fuel used.		0° F. if possible
Electric motors:			
Ring-oiled bearings	300 at 100°	180 to 200 at 100°	0° F.
Ball and roller bearings:			
Oil-lubricated	150 to 200 at 100°	100 at 100°	0° F.
Grease-lubricated	A grease of light or medium consistency		
Journal boxes	100 at 210°	60 at 210°	15° F. or lower
Miscellaneous other bearings:			
Oil-lubricated	300 to 500 at 100°	200 to 300 at 100°	0° F.
Grease-lubricated	Medium cup grease	Light cup grease	

Specific directions for winter lubrication are given in Chap. VI on winter care and operation of construction equipment. It remains to be stated, however, that in winter work it will be found economical always to provide a warm storage room for oils and greases. Machinery chilled

by standing out of doors puts enough handicap on the action of lubricants without also bringing them chilled to the work.

24. Explosives.—Many of the modern high explosives are low freezing; these should always be selected for winter blasting. The temperatures at which these explosives freeze are indefinite. They vary with conditions. The makers assert that: "Low-freezing explosives will not freeze under ordinary exposure to such atmospheric temperatures as are normally met with in this country." It is recorded where "non-freezing" dynamites have frozen at zero, and again where they have not frozen at 40° below zero. The way of intelligence for the constructor is to guard his explosives against freezing conditions.

25. Transportation Service.—Accessibility is influenced by winter conditions in a large way only in case of operations remote from railways or highways sufficient for heavy hauling. In these operations two ways, (*a*) spur railways and (*b*) tractor roads, are commonly employed to get from rail head to the construction site. In rare cases dog teams and pack animals are employed to get in special supplies and mail.

26. Railway Operation.—In operating standard-gage spur railways the usual railway methods and equipment for winter operation are employed. An example is the railway built to the Isle Maligne power plant on the Saguenay in the Lake St. John region of Quebec. Almost 30 miles of standard-gage railway were built here to serve the scattered operations of which 11 miles were in the main branch track from the Canadian National Railways. This 30-mile system was, like any regularly operated railway, equipped and organized for winter maintenance and operation, with snow plow, track gangs, and special gangs, as the necessities demanded. The winter operation of light railways calls for the same processes and types of equipment and organization. With heavy snowfall, the difficulties are increased by the smaller power and weight of the locomotives and rolling stock to drive through drifts and to keep to the tracks.

FIG. 9.—Tractor-packed snow road.

FIG. 10.—Tractor clearing a drifted road.

PLATE V.—Canvas enclosure for New Union Market building, St. Louis, Mo. Concreted partly in cold weather by Fruin-Colnon Contracting Company, St. Louis, Mo. Four-story and basement building one block square.

27. Tractor Operation.—In case of tractor roads, there are more special considerations. Here there is no heritage of proved practices to draw upon as is the case with railways. But the case is different in another respect: In general, winter, particularly if there is a good depth of permanent snow, improves road conditions. The road is usually over existing country wagon roads or forest trails; most often it is new road entirely or in part, is temporary, and is kept down to the most meager structure possible. It is these roads that frost and snow solidify and surface and turn into almost ideal tractor ways. Their maintenance, once the snow falls deep, comes from the tamping of the wide crawler treads and the surface packs harder and smoother (Fig. 9) as the tractor service increases. The tractor, too, is a good snow fighter (Fig. 10) when the need arises. Winter tractor haulage, then, is chiefly a problem of cold-weather tractor operating methods which are discussed in Chap. VI on Winter Care and Operation of Equipment.

As an outstanding example of winter tractor haulage, reference is made to the 30-mile haul (60-mile round trip) to the Baskatong reservoir dams for the Gatineau River power development in northern Quebec. The diagram (Fig. 11) shows the hauling record during one winter and summer; note the uninterrupted winter schedule, the effect of the spring breakup, and the uninterrupted dry-weather summer schedule. Winter haulage was as fast as summer haulage at its fastest. Indeed, the results were better in winter. Once steady cold had set in and snow had fallen, road maintenance was a negligible task; the traffic kept the road packed and surfaced. The winter task was equipment care and operation.

The hauling units, ten of them, were tractors with rear caterpillars and forward sled runners and load-carrying (8-ton) bodies. A tractor and a trailer made up a "train." The trailers were standard logging sleds. The operating schedule with two operators was a round trip (60 miles) in 16 hours, then a layoff for the crew of 16 hours. Three

trailers were provided for each tractor, allowing one at rail head being loaded, one on the road, and one at the job being unloaded. The tractors themselves, on each return to rail head, were run into the garage and carefully gone over, oiled, given fuel, and generally hostled, given body loads, and sent out with a loaded trailer. Generally a tractor made nine trips in seven days. The average load during the period covered by the chart (Fig. 11) was 18½ tons; the average summer load, with forward truck wheels on the

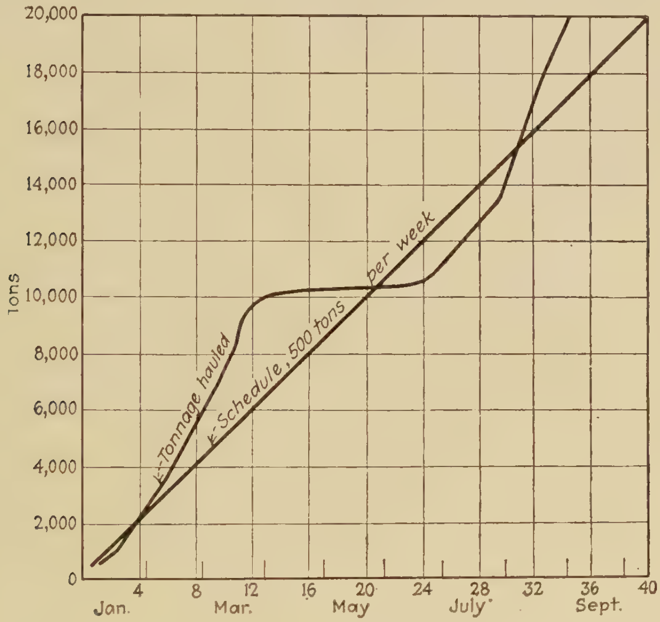


FIG. 11.—Chart of tractor haulage performance on snow roads.

tractors and wheel trailers, was 11 tons. The maximum winter load was 38 tons.

The schedule described was the winter schedule when hauling conditions were the best. The ground was hard with frost, the snow packed solid under the caterpillars, and the roads improved with travel. The tractors made better speed, suffered fewer breakdowns and required fewer repairs. The logging sleighs worked finely as trailers. Naturally, some cold-weather precautions had to be taken.

Kerosene was used in the radiators, and the tractors, when idle for any time, were kept in a heated garage; left outdoors, the caterpillars and radiators froze. In brief, the cold-weather precautions were simply those of which every automobile owner knows and practices.

28. Motor-truck Operation.—Like tractor haulage, motor-truck haulage is chiefly a problem of cold-weather operating methods which are discussed in Sec. 40. Successful operation of motor trucks is, however, largely dependent on road conditions. Hard roads are almost essential to regular schedules and cheap haulage. When these are available, motor trucks, within their load capacities, are excelled by no means of road haulage. They fail in deep snow or on soft-ground construction roads through woods and swamps. With hard roads snow removal is necessary.

29. Team Haulage.—Hauling with teams is hampered by fewer winter conditions than any other method. Teams can get into and out of places where no power-operated vehicle can go. On good roads and particularly on well-kept snow roads, the loads that can be handled by teams are considerable. Again teams can negotiate roads too unkept and poor to be used by motor vehicles at all. Their limitations are the physical endurance of the animals and the comparatively light loads which they can pull.

30. Snow and Ice Removal.—Two cases of snow and ice removal have to be considered: (1) snowfall which has to be cleared from tracks, roads, structures and working spaces, and (2) lodged and frozen snow which must be removed from forms and surfaces.

For snowfall removal, sweeping, plowing, shoveling, and hauling used everywhere and for all time are employed. The change that is noted, as in city and railway snow removal, is the use of power and machinery. On a large operation in northern Quebec, with some 35 miles of service track, a standard railway snow plow was operated with excellent effect and economy. Job roads and working spaces do not ordinarily offer the best surfaces for machine snow removal, but with a tractor and a V-plow or a blade

grader, many more places than would be expected can be got at effectively. A notable tool is the tractor with crawler traction. It will make its way through deep snow over rough ground and will pull or push plows and scrapers where other means of traction will fail.

Removal of lodged snow and ice from forms and surfaces to be built upon and worked over is a more particular task. Scraping and sweeping are time-honored and also time-consuming methods but they are effective and often they are the only practicable methods. For clearing forms and surfaces to be built upon, steam thawing is unsurpassed. Kerosene torch thawers are particularly useful, also, for removing ice and snow from reinforcement, structural steel, brick, and other material not injured by flame. Where heavy ice has occasionally to be picked and chiseled, speed and efficiency are gained by using pneumatic tools. These have been particularly effective in cutting ice from pavements and can be had of all compressed air tool makers.

31. Job Movement.—Transportation service includes consideration of intra-job movement. The means, standard, and narrow-gage service railways, tractor, truck and wagon roads, trestles, walks, stairs and ladders, are no different for winter than for summer. The special winter task is to remove snow and ice obstacles and hazards. Shoveling off snow, picking or thawing away ice, sanding walks and stairs, and installing hand rails are the simple operations. They are imperative and they require men and money.

CHAPTER VI

WINTER CARE AND SERVICING OF EQUIPMENT

Equipment which normally operates in the open requires special care and handling in winter. Equipment which is normally housed, as compressor and other power-plant installations, calls for no special winter care or handling, but the servicing of these installations with power and their own transmission of power service are operations in the open and so are affected by cold and snow. Job servicing of power is discussed in Sec. 42. The other practices of servicing, handling, and caring for equipment in winter are outlined here.

32. Plant Housing.—Plant housing divides into four classes: (1) permanent housing of fixed-equipment installations, as power plants and central mixing plants; (2) garages and roundhouses for mobile equipment, such as motor trucks, tractors, and locomotives; (3) isolated shelters for scattered pumps, hoists, etc.; and (4) machinery cabs or housing on the equipment itself. All these types of housing are about as commonly required for shelter in summer as for warmth in winter, and for winter their structure needs only to be tighter and to have heating service of such nature as is practicable or necessary.

33. Winter Breakage.—There is conviction somewhat supported by evidence that equipment breakages are more common in cold weather. Supposition that this is due to frost making the metals of equipment greatly more brittle has small support in our knowledge of materials. Ice, congealed lubricants, and frozen ground, however, stiffen up transmissions, weld and seal operating bearings and joints, and form a non-resilient foundation which often puts breaking stresses on equipment parts. The remedy is

to warm up or to thaw out, as described later, the stiffened parts by putting the mechanism gradually into operation or by heating, and to use more consideration of the rock-like rigidity of frozen ground when moving machines over it, or when otherwise working on it. In working excavators in frozen ground, there is temptation to use the bucket as a sledge to break down or as a crowbar to pry up frozen crust too thick to be so handled. Trying to pick up or to snake without loosening, piles, timbers or other objects frozen to the ground is a common cause of breaks in derricks, pile-driver catheads, etc. The examples can be multiplied. Those given, however, indicate clearly the nature of the causes of winter breakages of equipment so far as they differ from the causes which prevail at any time or temperature.

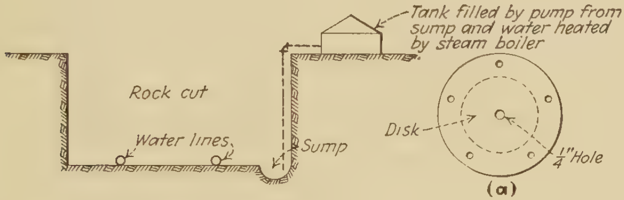


Fig. 12.—Steam-shovel water supply on St. Mary's River Channel Improvement.

34. Water Service.—Only large operations of considerable duration warrant trenching and pipe laying below the frost line. Two methods of winter operation of overground pipe lines are: (1) boxing and insulation and (2) intermittent use, draining, or blowing out the line between periods of use. Examples serve best to explain possible applications. Methods of camp-water supply are described in Sec. 14 and should be considered in connection with this section, which describes water servicing of equipment, on the work.

On the Neebish rock channel in the St. Mary's River between Michigan and Ontario, water was supplied to steam shovels through some 12,800 ft. of overground 2-in. pipe. Water was pumped from a sump to a tank on the bank as indicated by Fig. 12. The tank held about 6,000 gal. and at it were two pumps and a 35-hp. boiler, steam

from which, with exhaust steam from the pumps, was used to heat the water in the tank. The delivery pipe line was 2,500 ft. one way and 5,000 ft. the opposite way from the tank, and was laid with as few turns and valves as it could be. When the shovels wanted water it was pumped hot from the tank and kept constantly running until the shovel tanks were supplied, when the flow was shut off and the remainder water in the pipe line was blown out with compressed air. To avoid waste of air and loss of pressure in the air lines, air was admitted to the pipe through a constricted orifice arranged as shown at Fig. 12(*a*). This is an important practical detail. In two winters' work, seldom above

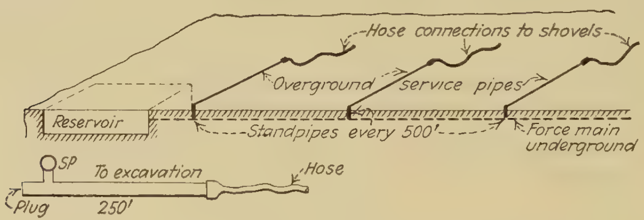


Fig. 13.—Steam-shovel water supply on ditch work in Western Canada.

freezing in January and February, the delay from frozen pipe lines was 2½ hours per winter per shovel.[1]

Winter water supply at an elevation of 7,600 ft. in January and February, 1925, at temperatures around $-40°$, for mixing concrete for the Mystic Lake power development in Montana, was protected as follows: The source was the lake 100 ft. lower than the mixer. Here an electric triplex pump was housed in and the house heated by electric space heaters. A 1-in. delivery pipe led from the pump to the tank alongside the mixers, the tank water being heated by steam. This pipe was laid overground (actually up a cliff) inside a 2-in. pipe kept filled with enough steam to prevent freezing. This arrangement proved most satisfactory.[2]

On steam-shovel ditch excavation in western Canada, water brought in tank cars was run into a track-side

[1] Grant, Smith & Locher Company.
[2] Winston-Dear Company.

reservoir and pumped through a 5,000-ft. pipe line to the shovels. The pipe was laid in a 7-ft. trench and had a standpipe and check valve every 500 ft. From the standpipes water was delivered to the shovels by a 250-ft. overground pipe and a hose connection (Fig. 13). This service pipe was covered with about 6 in. of manure and each time after taking water the steam shovel blew it clear with steam. This arrangement served all winter with temperatures as low as 50° below zero.[1]

Winter water-supply practice developed in operating a large fleet of shovels in coal mine stripping is as follows: Delivery is overground using 1½-in. pipe coupled with unions in sections not exceeding 200 ft. and connected at the shovel so that, by opening one valve and closing another, steam can be turned into the line or, reversing the process, water is allowed to enter the tanks at the shovel. At the source of supply which is usually a 10,000- to 20,000-gal. tank, the connections are boxed to prevent freezing. Just outside the box is a union which is uncoupled when water is not being used. In extremely cold weather a man is stationed at this union and, at intervals of approximately 30 min., the water is shut off, the union is broken, and steam is turned into the line. At night the lines are always blown out with steam and left uncoupled, and the first thing in the morning the lines are blown out before turning on the water. It happens sometimes, of course, when the source of supply is far away and the pipe lines are long, that before there is opportunity to blow back the line its entire length, freezing will begin. Then the unions in the line are loosened but not uncoupled as far back as the steam will force the water through the loosened unions. Beyond this point it is known that the pipe is frozen solid and this portion is taken apart and thawed in the usual manner.[2]

35. Practical Lubrication.—The kinds of lubricants best for cold-weather use were discussed in Sec. 23. At best they are compromises. Consideration under two heads is

[1] Grant, Smith & Locher Company.

[2] Central Pennsylvania Quarry, Stripping & Construction Company.

enough: (1) cylinder lubrication and (2) transmission lubrication. About the harshest conditions of both prevail in tractor and excavator operation. The lubricating oil used in a tractor motor, must necessarily be somewhat between that which will give perfect lubrication to the cylinder while at full-load temperatures and that which will be light enough to permit turning the motor over when it is very cold. With a too-heavy oil in very cold weather, when the motor is just started, the fresh oil will not be thrown onto the cylinder walls quickly enough to prevent undue wear after the oil remaining from the previous run has been used. Indeed, if a tractor or excavator engine is to be left standing in temperatures of zero or lower, only the lightest cylinder oil will meet the requirements for starting the motor cold. Yet such an oil is too light to lubricate the bearings and cylinder walls under full-load operating conditions without undue wear. Also, proper lubrication of the speed-change-gear, bevel-gear, and final-drive-gear compartments of tractors and the transmissions of excavators requires, in winter, a lubricant lighter than the heavy transmission oil used in normal temperatures. Here, also, the use of light oil involves the hazard of undue wear during full-load operation. A compromise is the result again, with not full satisfaction.

1. For the reasons indicated and because under even the best of conditions some time must be spent in starting and properly loosening up an extremely cold machine, it is real economy to provide some sort of warm storage wherever it is at all possible. Even where the contractor is shifting operations frequently he can usually, and should, equip himself with a portable garage in which a kerosene stove may be kept burning. Garage service applies, of course, particularly to tractors, motor trucks, locomotives, and similarly mobile equipment. It is usually impracticable for power shovels and other excavators; they have to be guarded as best can be done in other ways.

2. Where warm storage in garage is impracticable, other resorts are: (*a*) machine cabs which can be closed tight and

kept heated, manufacturers of excavators, cranes, etc. generally providing such housing as regular equipment; (*b*) draining radiators and refilling them when starting up again, using anti-freezing radiator solutions, draining out oiling system, keeping the oil warm, and refilling the system when starting up again, keeping the oil warm by a steam pipe through the system; (*c*) heating and watchmen to keep fires and guard against freezing; (*d*) warming up and thawing out machine parts preliminary, each time, to starting work. Some of these practices are developed further as in the following paragraphs.

36. Radiator Protection.—Frost protection of motor-cooling systems may be by draining or by anti-freezing mixtures. In draining, there is danger that there may be some pockets in the cylinder jackets which do not entirely empty; a precaution, then, is to run the engine a minute or two after draining to evaporate any pocketed water. Where operators prefer draining, it should be careful and thorough. In general, the use of anti-freezing mixtures is held preferable, a solution of alcohol or of glycerin and water, or it may be kerosene. The alcohol solution, say 40 to 60, or 50 to 50, is cheaper in first cost, but it evaporates more rapidly than glycerin. Whatever solution is used, it should be inspected at least once a day to insure that it has not changed strength and decreased its capacity to resist freezing. Kerosene cools satisfactorily and will not freeze, but carries a small element of fire hazard. When kerosene is used, the radiator cap should be removed and a standpipe the full size of the opening and 2 ft. or more high should be screwed on to prevent slopping and to carry the fumes well above the motor. Automobiles and truck and bus operation in winter have made the use of anti-freezing motor-cooling compounds reasonably familiar and practice for construction equipment need be no different.

37. Care of Power Units.—Frost has greatest effect on steam-power equipment, less on gasoline units, and least on electric motors. Indeed, electric motors are more efficient

electrically when cold so that the problem of winter handling involves only care in lubrication and protection from the wet. Steam- and gas-power units differ in their winter handling. Their handling on shovels, other excavators, and cranes working in the open covers all conditions of exposed use.

With steam power, when shutting down for the night or other long period, the steam chests and all pipes where condensed steam might freeze should be drained. Then keep enough fire under the boiler to prevent the water tanks from freezing. This calls for a night watchman. In the morning he should get up steam and have the machinery warmed up before the operating crew comes on duty. In starting up a steam unit it is a help to have a steam pipe connected through the mechanical lubricator to keep the oil warm and free-flowing. In greasing up, use hot grease.

With gasoline or Diesel engines, radiator protection by draining or by using non-freezing compounds comes first and has been described. Next is the selection of lubricants as previously outlined. Warming up the engine is, then, the main remaining winter requirement, and this varies in practice both in manner and duration. In general, the warming-up period must be long enough to bring the engine to a temperature where it will deliver the rated power. This period is reduced if the cab or house is kept heated over night and many operators provide cab heaters in winter. Some find it an advantage with Diesel engines to use a lighter fuel oil in winter. One operator outlines his practice with gas-engine excavator units as follows:

In winter a medium, or, in the cold northern states, a light oil should be used. The oil should be drained off at night and kept in camp where it will be warm in the morning to put back into the engine. This will avoid trouble from possible freezing up of the oil pump and will insure proper lubrication when the engine first starts to turn over. If it is not done, it is possible that some seizure in the bearings or some cutting may develop before the oil is thoroughly warm. In cold weather, the oil should not be

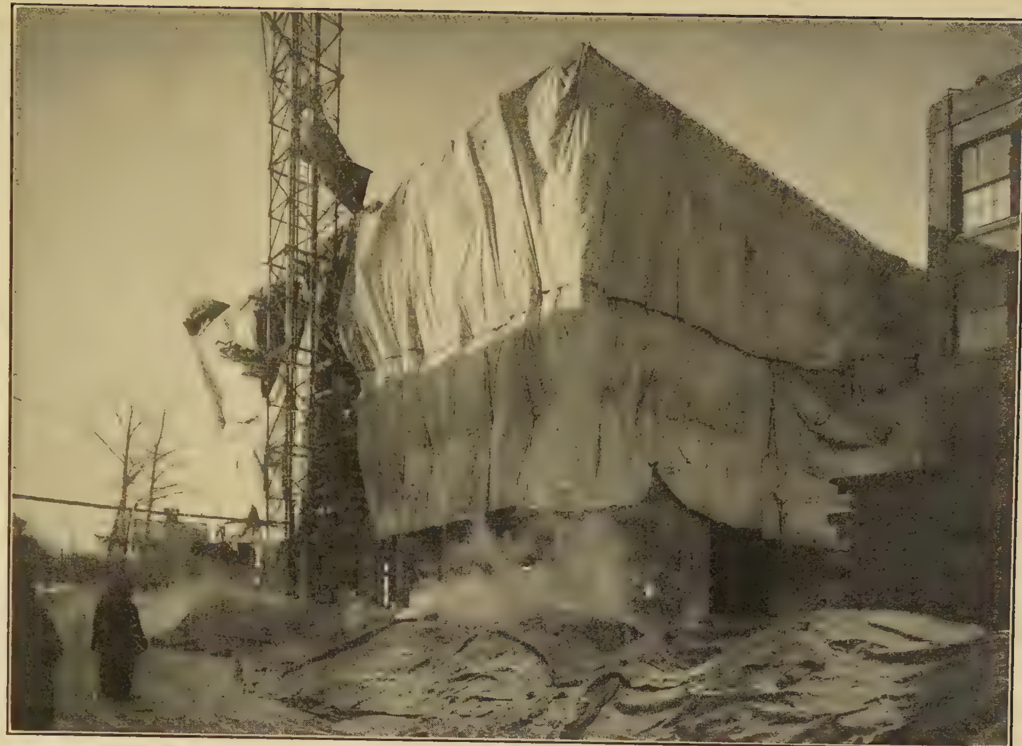


PLATE VI.—Canvas housing of factory building at Watertown, Mass.

Winter concreting operation by the Aberthaw Company, Boston, Mass. Note canvas-covered stock piles being heated by steam.

used at a maximum of more than two-thirds as long as it is in the summer. Not more than half as long would be still better, as the light oils will not stand up like the heavy oils suitable for warm weather. When the operator arrives at the machine in the morning, he should immediately put in the warm oil and start the engine, letting it idle while he greases up the rest of the machine. By this procedure, the engine will be ready to carry the load when the rest of the machinery has been greased.

38. Warming Up Tractors.—One of the most exacting tasks is warming up tractors of the gas-engine, crawler-tread type. The following directions contain many practices which can be applied to other gas-engine power units.

All tractors when shipped from the factory are lubricated for normal operating conditions. If a tractor is to be used in low temperatures, it will be necessary to change the oil as soon as it has been unloaded and operated long enough thoroughly to warm the oil in the motor and the various transmission compartments, so that it may be drained off. If the tractor is in a car, the interior of which is very cold, it may be necessary to warm the oil somewhat before the tractor can be unloaded with safety. The same condition may be encountered occasionally when it becomes necessary to warm up a tractor which is normally warm stored, and is lubricated accordingly, but which has been left out where it could get very cold.

If a steam jet is available, it furnishes the quickest and easiest method of applying heat. Otherwise, a gasoline blow torch, or a torch made of rags wrapped around a stick and soaked with kerosene, may be used. Care should be taken to apply the heat gradually to the various parts of any casting, that it may have time to expand equally throughout. The parts to which heat should be applied are, in order, the bottom of the speed-change compartment (this first, because it contains the largest quantity of lubricant, will take longest to warm up, and will hold the heat longest), the bevel-gear compartment, the final-drive-gear compartments, the cylinder walls and the intake mani-

fold. The carburetor bowl may be warmed just before the motor is to be started, by wrapping it in cloth and applying boiling water. Fire should not be used on the carburetor, due to the possibility of an explosion. Heat will reach the interior of the cylinder walls and the pistons much more readily if the cooling system is empty.

Particular care should be taken to apply heat to those parts where brass or bronze bushings are used. Brass contracts with cold more rapidly than does iron; therefore, at low temperatures such a bushing is likely to have a very close fit which will prevent lubricant reaching the bearing, when the tractor is started, in time to prevent damage.

If the motor crank case contains very light oil, and has been standing longer than over night, there will be a possibility that the oil may have drained away from the cylinder walls to such an extent that damage may result when the motor is started before fresh oil will reach these surfaces. In such cases, it will be well to remove the spark plugs and squirt a few tablespoonsful of oil on the top of each cylinder. The motor should then be turned over several times to allow this oil to work down to the rings and piston walls. This procedure will also improve the motor compression and thus facilitate starting.

Another method of warming the interior of the cylinders is as follows: Turn the motor over until the pistons are all equidistant from the tops of the cylinders. Remove the spark plugs and squirt a spoonful of gasoline on top of each piston. Then apply a lighted match to the spark-plug hole, keeping the hand and face out of the way of the resulting spurt of flame. This operation should be repeated half a dozen times for each cylinder. Sometimes the cylinder in which the exhaust valve is open will not ignite easily, in which case it may be necessary to burn out the other cylinders and then turn the motor over once to close that valve. This heating action, also, will of course, be more effective if the cooling system is empty.

If the gasoline available for priming the motor is lacking in volatile units, and so does not vaporize readily, it may

be necessary in extremely cold weather to use ether for priming the motor. This will rarely be necessary, however, if the cylinder walls and intake manifold are warmed as above outlined.

39. Freezing of Caterpillars.—Crawler treads will freeze if left standing in mud or water. Tearing them loose by throwing on the power invites tread breakage. At night the machine should be run up onto ties, timbers, poles, large stones, or anything which will lift the tractors off the ground. In case of freezing, any of the heating or thawing methods previously described can be employed to thaw the ice away. One operator who uses many steam shovels reports:

> Conditions govern our practice; if in clay or wet material, the caterpillar shovels are run up onto ties for the night, and if on rock bottom, a few rocks are thrown under the treads to elevate them. In the morning a steam hose is connected to the shovel and by playing steam a short time on the treads the caterpillars are free.

A gasoline-shovel operator states:

> When work is finished for the day the machine should, during the winter months, be traveled up on planks or poles laid on the ground. Where slippery ground has to be moved over due to sleet or ice or mud with frost underneath, it is well to put grousers on the shoes to prevent the machine from receiving or inflicting damage by skidding.

40. Operation of Motor Trucks.—Truck manufacturers commonly supply printed rules for truck operation in winter. They cover lubrication, use of choke, carburetion, radiator protection, use and care of brakes, care of tires, use of chains and care of the electrical system, all of which require a special cold-weather technique. With competent mechanics and drivers the best assurance that the rules will be followed is to provide proper garaging and to protect the driver and keep him comfortable by enclosed cabs or curtains. Housing of trucks and the shelter of drivers

reduce the time of putting up the truck at night and of taking it out in the morning and ensure repairs and adjustments which are pretty certain to be neglected or hastily and carelessly made if the work has to be done in the cold and snow. When depending on drivers to take the proper care of equipment on the road, much better attention is secured if they have closed cabs and all conveniences for doing their work. The contractor's business in operating trucks in winter is (1) to realize that there is a special winter technique of truck operation and (2) to provide garages, driver protection, and all means to ensure that this technique is followed.

41. Light Equipment and Tools.—Light equipment such as small pumps, portable air compressors, portable concrete mixers, air drills, and power hoists and all hand tools require winter care. Usually they operate intermittently and frequent shifting prevents permanent housing. They should be covered with tarpaulins when idle over night, or are temporarily laid up, to keep off snow and sleet. When working on wet ground they should be run up onto skids or planks to prevent freezing in. Where water is used in cooling systems, or moisture accumulates, or where water is handled, all parts should be drained and dried or removed from danger of freezing. When put into operation thawing and warming up should be scrupulously attended to by methods already described. Concrete mixers and chutes and buckets and other containers for carrying concrete should be washed or scraped clean of adhering material which will freeze. Hand tools should be cleansed of moist dirt or concrete and put in tool boxes or under other shelter. The amount and kind of care which will be required depends on conditions; good judgment will determine what needs to be done. The fact to be observed is that the task cannot be neglected. It is job enough to get a chilled machine going without having ice and snow to handle in addition.

42. Power Service.—Steam and gasoline equipment call for no servicing except fuel supply. Compressed air and

electric equipment require power-transmission lines. In the case of electric power, there are no different requirements in winter than in other seasons; the same rules hold good in respect to armoring, insulation, and waterproofing. Air lines, however, call for particular care in winter. With the loss in the air line of the heat of compression, compressed air loses volume and gives up some of its moisture. After-cooling and reheating, always desirable if the lines are long, is especially necessary in winter. Generally speaking, freezing in receivers and pipe lines is all that has to be guarded against, since air drills and modern pneumatic tools nowadays are invariably non-freezing. With air-operated engines and hoists, however, freezing at the machine may have to be guarded against. In air lines, traps and drain cocks at low points are needed. Automatic drop oilers set in the pipe line and feeding in turpentine or denatured alcohol will retard freezing. For reheating, manufacturers make special stoves. A coil in the pipe line with a wood fire inside is effective. In brief, air transmission in winter calls only for simple and easily secured means of protection but they are important.

CHAPTER VII

WINTER EXCAVATION AND EMBANKMENT CONSTRUCTION

Excavation and embankment construction in winter involves special methods mainly in moving earth. Rock excavation, except as it requires winter protection of explosives and the general job servicing and special power servicing previously described, has no special problems. Frost is a positive obstacle to easy earth excavation and embankment construction to a degree depending upon the extent of freezing, the character of the operation, and the methods employed. These influences can best be appraised perhaps by discussing excavation and filling operations along functional lines.

43. Storing and Thawing Explosives.—Low-freezing explosives are now made by most manufacturers. These ordinarily will not freeze at temperatures normally met in winter work. With their advent, attention to means of job storing and thawing has declined, but with the mercury hovering around zero there is enough uncertainty about their frost resistance to make it wise to house all explosives so that they cannot freeze. For this purpose the manufacturers have planned and will furnish plans of thaw-houses, or rather warmed storehouses, of various capacities and kinds to suit any ordinary requirement. The manufacturers' handbooks describing this equipment and its operation and the best procedures of protecting explosives are so generally available that the contractor is referred to them for detailed information.

44. Drilling and Blasting Rock.—Virtually all air tools including rock drills are made non-freezing so that, practically speaking, their operation in winter involves no procedures and precautions, except in connection with the air

lines and receivers, which are unusual in summer. There is, however, in winter work, particular reason for keeping the air dry. The methods of ensuring dry air and of keeping air lines from freezing and of reheating compressed air are described in Sec. 42. In general, steam drills are not advisable for winter work, chiefly because of the waste of power by condensation in the mains and because of hazard by freezing. Like drilling, blasting, with modern types of explosives and modern methods of firing, calls for no special precautions or procedures in cold weather. The obstacles to rock excavation in winter are not, to any considerable extent, due to materials, machines, or processes, but come from the exposure to which labor is subjected and which can be mitigated by good job servicing as described in Chap. II.

45. Drilling and Blasting Frozen Ground.—Blasting as a process of breaking up frozen ground has substantially the

Fig. 14.—Soil punch for driving blast holes in frozen ground.

same technique as blasting hardpan. The holes are made with a soil punch formed of 1½-in. round or hexagonal tool steel drawn at one end to a pencil point. The punch is driven into the frost crust with sledges and loosened by pounding on the sides. For driving in this way the punches should not be over 4 ft. long. A chain and lever

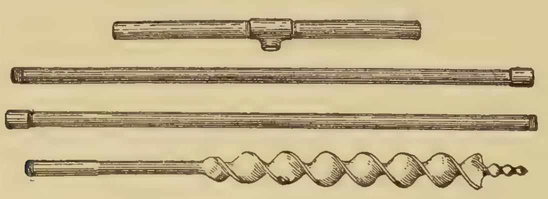


Fig. 15.—Soil auger for blast-holes in frozen ground.

can be used to pull the punch when pounding does not free it. A soil punch is shown by Fig. 14. After the punch is pulled the hole can, if desired, be reamed and deepened by

using a $1\frac{1}{2}$- to 2-in. soil auger of the type shown by Fig. 15. A little hot water poured into the hole will facilitate the use of the auger. Also Canadian contractors have found that using heated punches speeds up the drilling. In blasting the sizes and locations of charges will be determined by trial and observation.

Generally in breaking up frozen ground, blasting need not be resorted to except when the frost is deep; shallow frost crusts are readily handled by the power excavators commonly used. This statement refers to large open-pit excavations. For isolated column-footing pits and for trenches for wall footings where power excavators are not practicable, frost crusts can be broken up by blasting methods similar to those employed in blasting pole holes and trenches in hard ground. The holes are formed as previously described, generally one hole for a small column-footing pit and a row of holes for a footing trench. As the depths are shallow, light charges only are generally required; experiment will determine the proper size. The object is merely to break up the frost crust so that it can be lifted out and expose the unfrozen ground for excavation with pick and shovel.

46. Blasting Frozen Materials in Cars.—Gravel, sand, crushed stone, and cinders often contain enough moisture when loaded, or absorb enough rain or snow in transit, to freeze so that cars cannot be unloaded until the material is broken up or loosened. With care this can be accomplished, with light charges of explosives, without damage to the car. The method depends on how the material is frozen. Where there is only a frozen crust on top, holes punched, as previously described, about 3 ft. apart and extending just through the frost crust are blasted with light charges—a quarter- or a half-stick of 40 per cent dynamite. If the material is frozen pretty well throughout, deeper holes similarly charged will be required. In the case of steel hopper-bottom cars, the freezing may be mostly in the hoppers into which the water has settled. In this case the bottom doors are opened and inclined holes are driven up

into the frozen material but not quite through it, and are fired with a half-stick or a full stick of 40 per cent dynamite. In general, blasting frozen materials in cars calls for common sense and judgment rather than for any standard procedure. The danger always is in such circumstances that the men will become forgetful of the forces with which they are dealing and take chances with cap and fuse firing. This should be guarded against by putting a responsible man in charge of the operation. Always the safest firing procedure is electric firing.

47. Thawing with Steam Jets.—Thawing as a means of breaking up frozen ground is in general limited to small yardage operations in narrow areas, as footing pits or trenches. Generally, steam is the most practicable thawing agent, applied (1) through coils laid on the frozen surface, (2) by steam jet keeping warm water in the pit, and (3) by steam points melting their way into the frost crust. The third method is the most effective, and its technique for large operations has been highly developed in Alaskan gold mining where elaborate plants are employed. Those who wish to go into these practices in detail may consult *Technical Paper* 309, and *Bulletin* 259, Bureau of Mines, Washington, D. C.

In ordinary operations no such depths of frost, or such volumes and areas of material, have to be thawed as in Alaskan mining, but some notation of methods of the most common practice of steam point thawing is instructive. The main steam lines are boxed in or covered to reduce condensation. The laterals end in headers, or manifolds, to which several points are connected by hose; each header branch has a valve. The steam pressure is 100 to 150 lb. at the boiler. The points are $\frac{3}{4}$- or 1-in. extra-heavy hydraulic pipe. A tool-steel bit is welded to the lower end of the pipe and has a $\frac{3}{16}$-in. hole for the steam to escape. A driving head is attached to the top. Generally a square or a round taper bit is used. The points are spaced 4 to 10 ft. apart, depending on the depth and the character of the material. Muck thaws slowly compared to gravel; clay

thaws very slowly. Thawing costs from 10 to 30 cts. a cubic yard. Again it is emphasized that the frost is very deep and that the volume and area of operations warrant elaborate thawing equipment.

Steam points were successfully used in thawing a wide sewer trench in Boston, Mass., with a frost crust frozen hard to a depth of 34 in. The small steam shovel used could not break up this crust. Pipes laid on the surface, both open and closed, and well covered, were tried and thawed only 4 to 5 in. in 36 hours. Then steam jets were arranged as shown by Fig. 16. First, jet pipes, with ½-in.

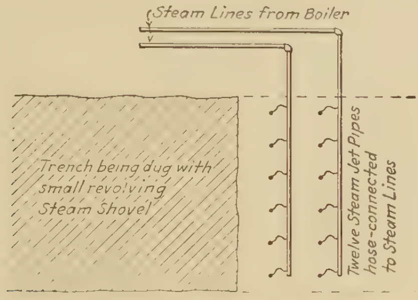


FIG. 16.—Steam jet arrangement for thawing trench cut.

open ends, were sunk through the crust. These were replaced with closed-end ½-in. thawing pipes having four ⅛-in. holes. These were left in the ground. Twelve pipes, six in a row, were used. All pipes were hose connected to the steam mains. This outfit softened the crust in 15 min. so that the steam shovel could handle it.

Steam jets and warm water have been used to advantage in sinking footing pits for columns. As worked out on building construction near Chicago some years ago, the procedure was to turn the jet onto the ground over the footing space and shovel away the thawed soil until a pit had been started which would hold a little depth of water. Then the jet was left inserted in the pool and periodically the thawed bottom was shoveled out; as the depth increased, the pit was curbed with the form boxes. By keeping jets

going in a group of pits, this procedure was quick and effective.

48. Thawing with Steam Coils.—Thawing with steam pipe grills has been most effective for trench work but it has occasionally been used for larger areas. Steam coils in units about 18 × 20 ft. made up of 13 parallel ¾-in. pipe

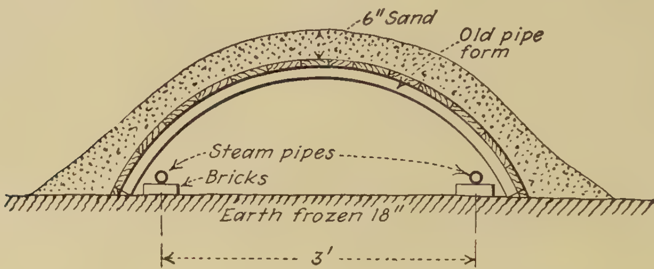


Fig. 17.—Housing for pipes for thawing trench cut.

(260 lin. ft. aggregate) were used in groups of six to thaw ground for concrete-floor slab in a building 300 × 350 ft. in New York. The frost was about 2 ft. deep. The coils were fastened to two 18-ft., 2 × 4 in. studs for handling and when laid down for thawing they were covered with canvas laid on 2 × 4's, 3 ft. apart across which were 2 × 4's and a second canvas cover.

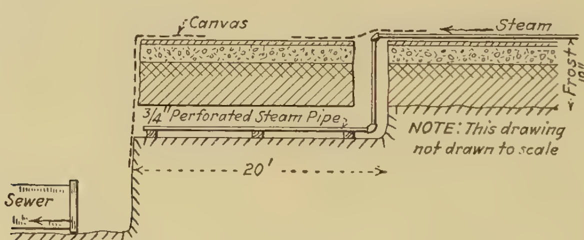


Fig. 18.—Thaw-pipe in under-crust tunnel for trench cut.

On sewer trenching near Toronto, Ont., with about 3 ft. of frost, grids seven pipes wide and about 7 ft. long were laid end to end on the ground over the trench line, covered with 8 in. of manure and supplied with steam by a vertical boiler on a carriage. The pipes were 1 in. spaced 1 ft. apart and enough grids were supplied to provide for 24 hours

PLATE VII.—Canvas floor protection for concrete building.
Concreting operations on Dec. 31, 1923; A. M. Allan and Company, engineers and architects.

thawing ahead of excavation. At the fastest, progress in trenching and pipe laying (45-in. concrete) was 50 ft. a day.

In building a sewer at Kalamazoo, Mich., the arrangement shown by Fig. 17 was employed. A 1-in. pipe was run along one edge of the proposed trench for 100 to 150 ft., turned across and returned along the other edge. To keep

Fig. 19.—Winter trenching with shovel and clamshell.

the pipe off the ground it was supported at intervals on bricks and the whole was roofed over with segments of old sewer forms covered with 6 or 8 in. of sand. A boiler on a truck supplied steam. About 24 hours was enough to thaw through up to 18 in. of frost; this was then excavated and the thawing outfit was moved ahead. A portable shelter was built around the boiler. Thawing a trench 36 in. wide cost 10 to 30 cts. a linear foot.

Another thawing arrangement for sewer trench is shown by Fig. 18. There was 18 in. of frost under the pavement. A tunnel 3 ft. in diameter was driven ahead 20 ft. in the ground under the frost crust and at its end a shaft to the surface was excavated. A steam pipe from the trench excavator boiler was arranged as shown. The heat in a few hours loosened the frost crust and the pavement was cut through and the trench dug in the usual manner. Fig. 19 shows a trench excavation in winter using power excavators.

49. Picking and Chiseling.—Breaking up frozen earth by picking and chiseling calls for little explanation other than to direct attention to the possibilities of pneumatic tools

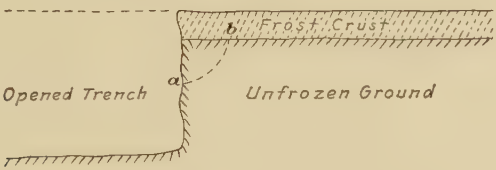


FIG. 20.—Chiseling down frozen crust in trench cut.

compared with familiar hand methods. Any of the "pneumatic diggers" manufactured for digging hardpan and cemented gravel or for breaking pavement can be used, with spade or chisel steels, for breaking up frozen ground. They are particularly effective in breaking down frozen crusts a foot or so thick in trenching. The outfit is substantially that used for cutting out pavement—a portable compressor and a light-weight air tool fitted with a bull-point or chisel steel. A particularly effective procedure in trenching is indicated by Fig. 20. With the trench started, the crust is undermined as indicated at *a-b* and then, with the pneumatic tool, it is chiseled down in successive cuts. This same general method is efficient, in open-pit work with power excavators, for breaking down the frozen crust at the top edges.

50. Drainage.—Drainage of pit and trench excavations often presents a troublesome problem in winter. On

occasions when water comes from general light seepage, frost may be a decided advantage in sealing the ground with ice. Where considerable flow from springs or veins requires ditching, sumps, and pumping, the problem becomes one of keeping ditches open and pump suctions and discharges clear of ice. If the ditch is one which will be permanent during the operation, freezing can often be prevented by digging it deep, carrying a good depth of water, and roofing it with boards and dirt, or allowing an ice crust to form, under which the water can flow. A good current is a great preventive of ice formation and measures to keep up a steady flow by pumping or ample fall in the ditches, should be employed. A steam jet in the sump, suction, and discharge pipes boxed in as described in Sec. 14, and heated pump housing are other cold-weather precautions. The conditions and requirements of excavation-pit drainage in winter are so various that judgment must always determine the means. It is entirely practicable in some operations to let water and frost have their way and do no constructive drainage until warm weather loosens the ice and the water has free flow. Again, the conditions and requirements may be such that immediate and continuous removal of the water is necessary. Then drainage works are necessary, and all the precautions which are needed to keep them free from freezing have to be employed. In ground soft with water, but giving off no considerable volume of water, freezing may be a decided help to excavating operations by solidifying the pit floor.

51. Protecting Excavation Bottom.—Trenches and pits intended to receive footings require preservation from frost until the masonry is placed, and so generally does excavated earth emplacement for structure of any sort. No foundation should be placed on frozen soil. Pit and trench sides ordinarily may safely be allowed to freeze if thawing will naturally occur before the backfilling is placed. Putting in backfilling against frozen sides is not well and particularly it should not be put in on top of ice and snow frozen in the bottom between wall and trench side. Keeping frost out

of the excavated foundation bed until the masonry is placed is, however, the paramount requirement. Generally, a covering of straw or manure will protect the bottom if there is no water, or the excavation can be covered and kept warm by oil or other heaters. Ice and frozen snow on foundation beds are as bad as frost in the ground and should as religiously be prevented or removed. Where large areas are to receive slab or mat foundations, blanketing with straw or manure will prevent freezing for the usual period necessary. Straw covered with canvas has been very successful in protecting road subgrade as described in Chap. IX. In general, a rule for contractors in preparing to build on earth foundation beds in winter is: Prevent frost or, if this cannot be done, find frost and remove it.

52. Dry Fill.—Frost is an obstacle in placing fill; the material freezes in the cars, frozen material is harder to spread, frozen tracks are harder to shift, and frozen material in the fill prevents settlement until thawing occurs. In general, fills to be built upon or to impound water can be made in winter only with many precautions, unless they are to stand before use long enough for thorough thawing and final settlement. Embankment construction in spread and rolled layers virtually demands unfrozen material. Dumped embankment can be built of earth containing frozen chunks, but it has to thaw out before attaining settlement and position.

53. Hydraulic Fill.—Ordinarily, hydraulic fill in winter is held impracticable. In dam building in Michigan in 1918, however, some 300,000 cu. yd. were placed between October and April with average monthly temperatures ranging from 5 to 35°.

Most of the earth was obtained from a high bluff near one end of the dam, being transported to place in the earth embankment by means of sluicing troughs carried on wooden trestles. These sluicing troughs were for the most part made from No. 10 gage steel plates, and were approximately semicircular in shape, with a diameter of 30 in. The troughs were 10 ft. long, and were so placed on the

trestle that they overlapped each other a few inches. The sluicing grade was from 6 to 8 per cent, and in ordinary weather no trouble from leakage was noted. In extremely cold weather, however, it was found that there was a tendency for the slight back leakage through the joints between the troughs to form ice which gradually built up, lifting the lower end of each trough so that the effective sluicing grade was materially flattened. This made it necessary to remove the ice from the joints at frequent intervals, so that the sluiced material could be transported on the proper grade.

Centrifugal sluicing pumps were utilized, all of them being motor driven. All the pumps were housed in, and no especial trouble from freezing was encountered on account of the very cold weather. As long as the water was kept in motion through the sluicing pipes, there was not much delay from freezing, but if, for any reason, the flow was stopped, it became necessary to thaw the pipes. The construction organization became so proficient in the use of the plant, however, that comparatively little delay was caused during the winter on account of freezing of the water supply. Constant attention was required to keep the ice removed from the sluicing troughs in order to prevent obstruction to the flow of the sluiced material, but it was found that with a reasonable amount of attention very little ice was deposited in the embankment and there was no tendency for the sluiced fill to freeze so long as water was allowed to run over the surface.

When the temperature remained below 15° for more than a few hours, sluicing was stopped. The embankment surfaces under construction were cleared of snow and ice when starting anew. In some cases, where it was not possible to make a continuous fill, the ground froze, and it became necessary to utilize steam jets for thawing the frozen material before sluicing was resumed in that particular location. These steam jets gave very satisfactory results, and it was found possible to thaw a surface of considerable area by means of one pipe left in place for several hours.

CHAPTER VIII

ICE SERVICE AND HAZARD IN WINTER WORK

Ice considered in mass, as the winter covering of streams and lakes, offers both hazards and helps to construction. Canadian constructors have developed a keen wit in utilizing ice on streams for doing many things. They, too, have led in developing means of overcoming the hazards of moving ice. These uses and hazards of ice are briefly summarized. Incidentally, the uses are apart from the value of ice in solidifying soft ground and marsh and in sealing up seepage in excavation, which have already been mentioned. So, also, the hazards are apart from those due simply to freezing. They are the helps and hazards of ice as it bridges water and develops movement in freezing and thawing and with the rise and fall of water levels and with the surge of waves and the force of currents.

54. Putting Ice to Use.—The ice bridge of winter offers a convenient means of working from the surface of streams and lakes. Its use as a means for making soundings, borings, gagings, and other bottom and flow surveys will occur to all. Another outstanding use is in installing plant and equipment. Important preparatory work of many kinds can be performed by means of the ice bridge such as swinging across-stream cableways, cable foot bridges and trestles or in putting equipment across stream for spring excavating operations. Similarly, it can be used as a working platform in sinking caissons, cofferdam cribs, and other in-water structures. Examples of these uses follow.

55. Cofferdam Construction.—In building the Isle Maligne dam on the Upper Saguenay in northern Quebec, the frozen river was utilized in cofferdam construction as

shown by Figs. 21 and 22. Other reasons than the service that a frozen stream could render dictated cofferdam building in winter and the ice aid was only incidental, but

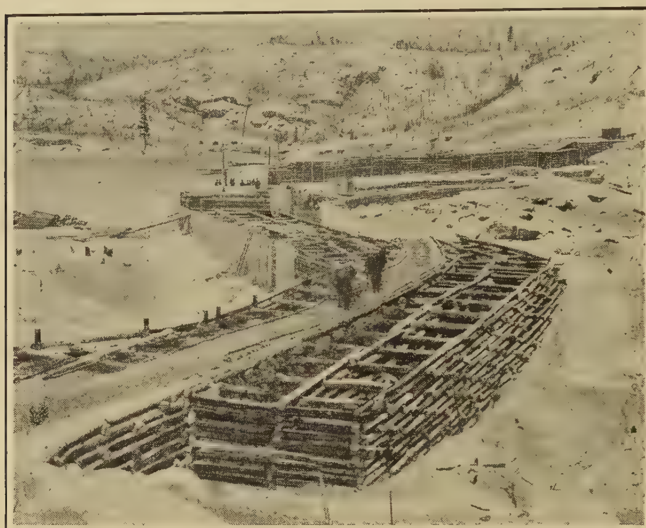


Fig. 21.—Cofferdam built through ice, Saguenay River, Quebec.

the operation illustrates a possibility. A condition here peculiar only to far northern swift streams was frazil ice.

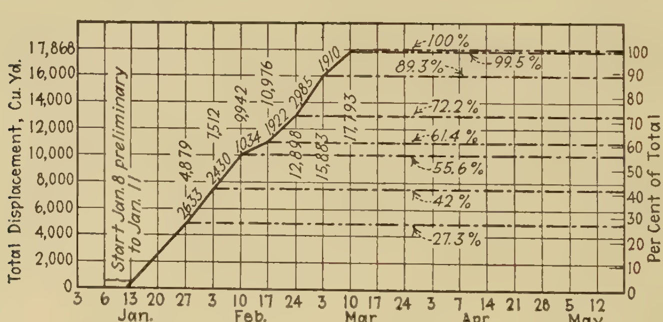


Fig. 22.—Progress chart in building Saguenay River Cofferdam.

The situation in brief was this: The river had frozen solid part way out from each bank but in midstream the swift current had prevented freezing, although the water was

thick with the masses known as frazil, ready to congeal and solidify once the speed of flow was checked enough to afford the opportunity.

Working from the partial ice bridge on each side of the stream, brush booms were thrown across midchannel. These gave a slight check to the current and also a collecting place for ice with the result that the frazil congealed and built up an ice closure across midchannel. Through the completed ice bridge the cofferdam cribs were sunk and filled with stone. The illustrations show the ice conditions and the speed of construction.[1]

56. Building a Water Intake.—The ice covering on Morris Lake reservoir for the water supply of Newton, N. J., was used in the winter of 1927 for placing an outshore intake. The intake was built on shore of reinforced concrete in two exteriorly cylindrical shells, one to sit on top of the other. The top section had an integrally molded spout-like branch on one side of the cylinder for connection with the intake pipe line but the bottom section was a plain cylinder. The bottom section weighed about 12 tons and the top section about half as much; both sections were 8 ft. in outside diameter. The depth of water was about 35 ft. where the intake was sunk. The ice covering was 18 in. thick when placing was started. A heavy timber sled was built, as shown by Fig. 23. The runners, 40 ft. long, were trussed to distribute the weight on the ice and also to provide means to lift the concrete cylinders off the across-runner timbers on which they sat when traveling, and then to lower them into the water.

With the sled near shore the bottom cylinder was lifted by a 10-ton crane on crawler traction and sat on the cross-timbers. The cylinder weighed 12 tons and the sled 5 tons, making a 17-ton load. A small hole was cut through the ice, beyond the intake location through which a cross-log with a cable attached was placed under the ice to serve as a deadman to hold a snatch block. A cable from the crane on shore was then run through the snatch block and

[1] Quebec Development Company, Isle Maligne, P. Q.

back to the sled. After the sled runners were broken free, the load moved easily out onto the ice and into position for sinking. The ice sagged but did not break. The pulling line from the crane was shifted from the deadman block to the double blocks on top of the sled and the cylinder hoisted off the cross-timbers. A hole was then cut through the ice and the cylinder was lowered to the bottom of the reservoir. The same procedure was followed in handling

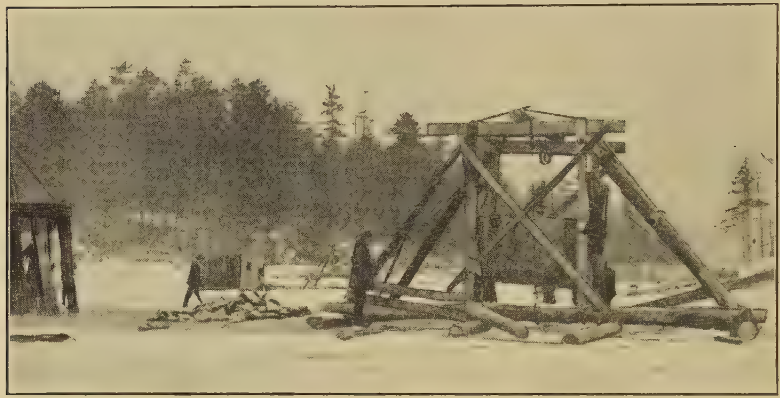


FIG. 23.—Sled for hauling section of concrete intake over ice.

the top section of the intake. It will be noted that a concentrated load of 17 tons was carried by 18 in. of ice.[1]

57. Transporting Equipment.—In building Lock No. 4 of the Champlain branch of the New York Barge Canal, a large part of the contractors' equipment was taken across the Hudson River on ice in February, 1909. The distances, the track system, and the ice thickness are shown by Fig. 24. Originally the ice thickness was less than 9 in., and it was built up to the figures shown, by cutting holes and pumping water onto the surface to freeze. In flooding the surface, snow was removed down to the clear ice; the result was no snow ice but probably not the best quality of clear blue ice. The plant moved comprised three locomotives stripped down to 15 tons, a steam shovel boom weighing 15 tons, a steam shovel dipper weighing 10 tons, and various

[1] H. G. Payrow, Lehigh University, Bethlehem, Penn.

PLATE VIII.—Blow-pipe thawing torch on steel erection in winter.
Girls' high-school building, Brooklyn, N. Y.; George A. Fuller Company, New York, contractors.

hoisting engines, dump cars, drills, and smaller tools, some of the loads reaching 12 tons. It was originally planned to take across the steam shovel, weighing 45 tons, with boom and dipper removed, and otherwise stripped down, but after experience with the locomotive loads the three-times greater load seemed too hazardous to attempt.

As shown by Fig. 24, the track support was not uniform, first because such timbers as were at hand were used and second because in dropping down the ramp off the dock at Stillwater it seemed wise to concentrate supports. The loads were hauled on their own wheels or on cars by a hoist-

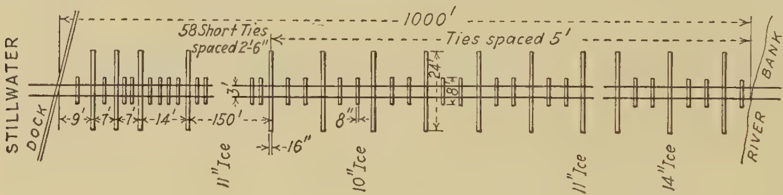


FIG. 24.—Track on ice for carrying equipment across river.

ing engine, on the east shore, with a 1,000-ft. cable. This method required no men on the ice. The lighter loads were taken over first, then the locomotives and finally the shovel boom and dipper all singly. Starting at daylight, the operation was continuous until two o'clock the following morning. In taking the locomotives across, observations were made with a level. Before any loads were moved across level readings were taken on the track. Then with a level rod attached to the locomotive, readings were taken all during the 4-min. trip. These showed that the ice took on a long undulating movement as the load advanced. The average sag was 4 in. and the maximum sag 6 to 7 in. The ice cracked and shattered badly under the repeated loads and water came through. It was judged that the 15-ton loads were about the maximum that 10 in. of ice would carry.

58. Laying Subaqueous Pipe Line.—To connect the intake sunk through ice on Morris Lake reservoir, as previously described, with the gate house, 600 ft. of 20-in.

reinforced-concrete pipe precast in sections, with special joints, were sunk through 18 in. of ice in water varying from 15 to 30 ft. deep. The sections of pipe were hauled to place over the ice by teams. Then a slot was cut through the ice with ice saws and over the line of the pipe. The pipe sections were rolled onto planks bridging the slot. They were then picked up by chain blocks on tripods and lowered to the bottom where a diver made the connections.

Fig. 25.—Cribs for lowering intake pipe line through ice.

In constructing a 20-in. cast-iron pipe intake for the water works of Iron Mountain, Mich., the ice on Lake Antoine was trenched and the pipe lowered in 1,000-ft. sections. This intake had a total length of 3,300 ft., with 2,200 ft. extending into the lake and the remainder extending from the shore inland to a pumping station. The pipe laying was carried on during January and February, 1926, at an average temperature of 18° below zero. At no time did the

temperature get above zero for more than an hour or two and at times it reached 28° below. The entire line was first laid and connected on top of the ice which was 38 in. thick. Then cribs were constructed at 36-ft. intervals as shown by Fig. 25 and slings of cable were attached to the pipe at each crib as shown by Fig. 26. Threaded rods passing through cross-timbers spanning the pipe between cribs were hooked into the slings and held by steel plate washers and nuts on the tops of the timbers. A strain was taken on the pipe line by screwing up the rods and then a trench was cut through the ice directly under the pipe. About 1,000 ft. of pipe were lowered at a time by turning the nuts and screwing down the rods. When the first rods were lowered their full length, a second set of rods was placed in position and hooked onto extensions of the slings. Enough water was admitted to each section of pipe line as it was being lowered to overcome the buoyancy of an empty pipe which for a 20-in. class *A* cast-iron pipe was sufficient to float the pipe when barely submerged. The amount of water admitted during lowering was regulated so as not to put too great a strain on the lowering rods. Lead joints were used with swivel joints at three places.[1]

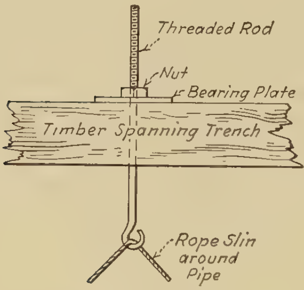


Fig. 26.—Detail of lowering device in operation shown by Fig. 25.

59. Ice Hazards.—The expansion thrust of ice and the formation of ice jams may endanger construction operation by weakening and displacing falseworks, cofferdams, trestles, etc., by pressure, or by damming back the water so as to flood the work. Ways of mitigating these hazards have been fairly well worked out. Ice floes lashed by waves in open waters or carried by swift currents offer a more difficult problem. Then it is only by sheer strength of structure that safety can be assured.

[1] F. W. Hartman, city engineer.

60. Ice Thrust.—The thermal expansion of ice is a familiar phenomenon. It causes the ice sheet on lakes and ponds to travel up the shores and to exert tremendous pressure if confined. The danger of pressure from ice fields is increased by wind action and by fluctuation of water level. Dam failures due to these causes have been recorded. It is stated that ice may expand 0.00025 to 0.00066 ft. per lineal foot of reach. The force of expansion to be considered is the crushing strength of a field of maximum thickness; various authorities place this strength at 12 to 25 tons per square foot. The values to be assumed for ice thrust is then a matter of judgment. At the O'Shaughnessy dam at Columbus, Ohio, the pressure per lineal foot of exposed crest was assumed as 17 tons; as 23½ tons at Wachusett, Ashokan, and Kensico; as 12 tons at Cross River and 15 tons at Croton Falls, and as 25 tons at La Loutrie dam, St. Maurice River, Que. These figures are given merely to indicate the magnitude of ice pressures which dam designers have thought it wise to guard against.

In temporary construction-plant structures, the hazard of ice thrust is prevented by keeping open channels cut around the structure, by preventing ice from freezing against the structure, or by rotting zones of weakness which will crush and take up the shove of the expansion. Keeping open channels calls for no explanation; ice saws and ice hooks are the only means required. Steam pipes laid around the structure at water level will prevent the ice from freezing close and give room for expansion. They are often used in very elaborate arrangement to keep intake screens and gates from being icebound. At the Keokuk dam across the Mississippi River compressed air pipes were used to keep open water next to the gates. The pipes were placed under the surface and the air escaping through perforations kept up an ebulition which prevented freezing.

For construction work where, ordinarily, the task is not to keep working mechanism free but merely to prevent dangerous thrust against temporary structures, the more practicable method is to rot the ice by chemicals or other

means. Salt, calcium chloride or calcium carbide, and sulphuric or hydrochloric acids will rapidly rot and destroy ice. Calcium chloride will go through the hardest ice sheet in the coldest weather, leaving it rotted and weakened to such an extent that it will take up ice thrust by crushing. With ribbons of calcium chloride spread close to the structure and in parallel lines farther away, zones of weakness in any desired location can be multiplied to any number desired.

61. Ice Jams.—Where ice packs up and forms jams or gorges which choke the flow and dam back the water so as

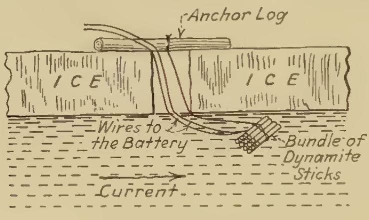


Fig. 27.—Dynamite charge for blasting ice jams.

to endanger construction structures by flooding, the only resort is to break the jam. The most familiar method is to use dynamite. This calls for judgment in selecting the key or pivotal point of the jam or gorge and in selecting the proper sizes and locations for the blasting charges.

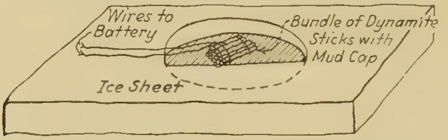


Fig. 28.—Mudcapping to break up ice floes.

In general, there are two methods of placing charges: (1) Holes are cut through the ice, and bundles of dynamite, the amount of which must be determined by the thickness of the ice, tied to anchor logs are thrust through the holes and are allowed to float under the ice a little way from the holes. The firing wires and caps are fixed to the charge before it is floated under the ice. The arrangement is

indicated by Fig. 27. (2) Large mud caps are located on the top of the ice at frequent intervals, as indicated by Fig. 28. Electric firing should be used for safety and so as to get the benefit of simultaneous explosions.

A blasting procedure for removing ice gorges is indicated by Fig. 29. It consists in breaking out a channel through the ice mass, in the line of the current, from the downstream to the upstream edges, by taking out successive bites as indicated. It is hard to specify definite amounts of explo-

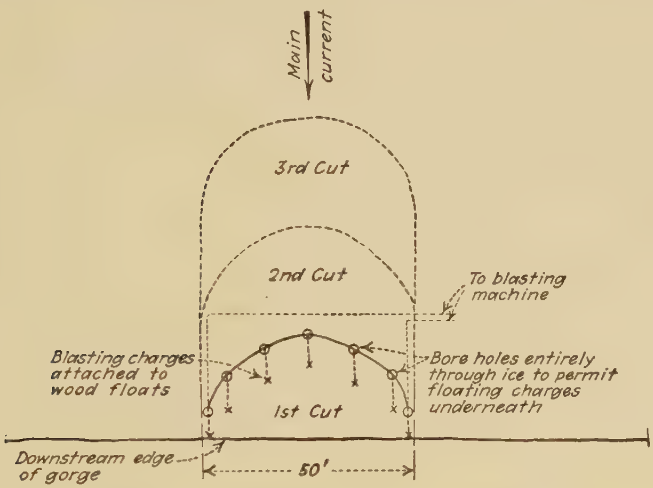


FIG. 29.—Blasting plan for removing ice jam.

sives. Charges of 10 lb. will break up ice masses 3 to 4 ft. thick, but where 30- to 40-ft. gorges have formed, charges of half a ton may be required. Usually the tendency will be to underload. Dynamiting ice is extravagant in explosive in proportion to the results secured.

In the last few years a method of breaking up ice jams by means of thermit bombs has been highly developed by Prof. Howard T. Barnes, of McGill University, Montreal. Numerous jams have been successfully removed by Professor Barnes. The method calls for skillful direction and the services of the inventor are advised to those who have the problem.

CHAPTER IX

CONCRETE-PAVEMENT AND ROAD-BRIDGE CONSTRUCTION IN WINTER

Highway construction in cold weather develops special problems, mainly in paving. These, however, are so troublesome that paving in winter can in general be undertaken only as an emergency operation. Excavation and embankment and bridge construction in road building offer the same obstacles, which are overcome in the same manner as in other kinds of engineering work. Paving, on the contrary, opens up a set of conditions which are peculiar to itself. The work is in the open and subject to every rigor of frost and storm; hauling is a major and constant operation; water supply is a necessity by overground pipe lines of great length; construction plant and operations are continually moving; the structure is a thin slab in contact with the cold ground below and the frosty air above. All these conditions curb easy resort to the usual means of combatting frost.

62. Concrete Mixtures.—Concrete reacts to cold in road work as it does in other construction. Also, the same conclusions in general hold regarding cold-weather use of special cement concretes and high early-strength concrete mixtures (Chap. X). The rapid development of strength and the more intense heat generation of these special concretes have, however, a particular appeal to the road builder. Pavement slab has large exposure in proportion to volume, and the effect of cold is rapid, and the area to be protected is great. Protection is a continuing operation as is the slab construction; the adopted means of protection—insulation, enclosure, heating—has to be continually moved ahead. Repetitive use is, then, of the highest economic importance, and the shorter the period of required protec-

tion the more often the protection units can be reused and so their number and investment cost reduced. The special concretes referred to, by their early high-strength qualities, cut down the time after placing for which frost protection is necessary.

Actual use in road building of alumina cement concrete or of high early-strength portland cement concretes, specifically to lessen frost hazard, has been of a rather tentative nature. In Massachusetts, in 1923–1924, a state

FIG. 30.—Alumina cement concrete temperature graph in Massachusetts pavement.

road job at Wilbraham extended into the winter and Lumnite cement concrete was adopted. Cold materials were used. In one place where a temperature record was taken, the sand and gravel both contained frozen lumps and a Hauck burner was used in the mixer; the concrete when placed was 65°. Records taken by a thermometer inserted in a 4-in. hole in the slab 8 in. thick gave the graph (Fig.

30). Another record from a section of alumina cement road constructed in Missouri is shown by Fig. 31.

In this work the concrete was poured with particular attention given to the regulation of the factors which would influence the early strength of the pavement. The concrete was delivered to the subgrade with a 1½-in. slump where it was finished by hand after being mixed from 2½ to 3 min. in a two-sack mixer. The temperature of the aggregate was approximately 30° F. and the water 34° F., and the resultant mixed concrete had a temperature of approximately 40 to 46° F. No water or cover was used in curing the pavement except on the concrete poured late in the day on the first half-section which was covered at night to protect it from freezing. The construction of the second half-section was the same as the first, except that it was not necessary to cover the slab at night, due to the milder temperature. A series of temperature readings of the air, earth, and concrete were made at regular intervals during the curing process, especially during the period in which the alumina cement concrete was obtaining its set and heat evolution was the greatest. The temperature readings of the concrete were made (1) by inserting the thermometer in the concrete to obtain the interior temperature of the slab; (2) by covering the slab with a heavy blanket and recording the temperature of the concrete under the blanket.

Graphs 1 and 2 of Fig. 31 show the temperature relation between the surrounding air and alumina cement concrete, during the hardening period of two different batches of concrete which were under observation. Graph 3 shows the temperature relation between two batches of concrete and the surrounding air and the earth during the period of hardening. The temperature of the concrete for the first 4 hours after leaving the mixer was lowered, due to the low air temperature, and the curves indicate that the pavement should be protected from freezing during this period, especially if the temperature of the air is extremely low. The concrete begins to generate heat about the time it gets its initial set and the temperature curve rises at this period

even though the air temperature is near the freezing point. The surface temperature readings, as recorded by the curves, are probably a little higher than the actual tempera-

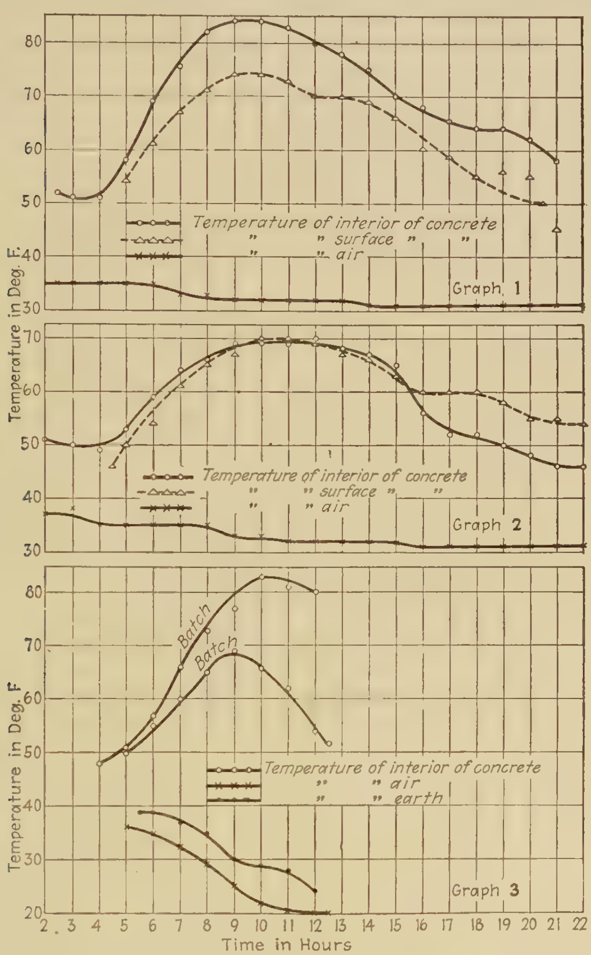


FIG. 31.—Alumina cement concrete temperature graphs in Missouri pavement.

ture of the concrete, due to the fact that the heat evolved was held under the blanket and not permitted to dissipate freely. The concrete generated enough heat to keep itself from freezing, without protection, during the hardening period, even though the air temperature was

below freezing, and no additional protection was required following the initial set.[1]

When either special concretes or accelerating admixtures are used, it must be remembered that they are not substitutes for heating the materials and sheltering and keeping warm the placed concrete but are used only as a means of shortening the curing period for which protection is necessary. This subject is more fully discussed in Chap. X.

63. Preparing and Protecting Subgrade.—Methods of excavating frozen ground have been discussed in Chap. VII. Prepared road grade, that is, grade ready for the lesser earth-moving operations of shaping and finishing to produce the fine subgrade, where deeply frozen, offers a nearly impracticable task of preparation. The concrete cannot be laid on frozen ground or ground that is soft with mud from thawing. To thaw any considerable depth of frost calls for such an amount of plant and time that the operation is out of the question. Preparing and protecting subgrade, then, as it is considered here, contemplates handling only shallow crusts of frost and keeping them from forming. The methods are: (1) blanketing the unfrozen ground with straw or other covering to prevent freezing; (2) using a grid or lines of steam pipe under canvas or other covering; (3) tenting over the road and keeping the enclosure warm. The second and third processes are also used for thawing light frost crusts. Examples of all these methods are given in succeeding sections.

64. Heating Concrete Mixtures.—Long carriage of aggregates and long overground water supply make heating of concrete mixtures a particularly hard task. Heating the water can be rather simply managed at the mixer, using either commercial water heaters or job-devised pipe coils enclosing wood fires, once the flow to the mixer can be maintained against frost. Something also can be done with the aggregate to the extent of seeing that it leaves the proportioning plant thoroughly thawed. On the whole, however, the most manageable method of getting hot

[1] T. H. Cutler, Chief Engineer, Missouri State Highway Commission.

mixtures appears to be flame injection into the mixer. This method is discussed in Sec. 80. Where considerable temperature of mix is required, the flame heater would seem to have its proper role in maintaining in the mixer the temperatures put into the water and aggregates. Practice calls for higher temperatures of concrete in place in pavement slabs because of the excessive exposure; some engineers urge that the concrete should go into the slab at 80 to 85°.

65. Protecting Placed Concrete.—Conservation of heat in the constructed slab calls for quick placing and as dry a

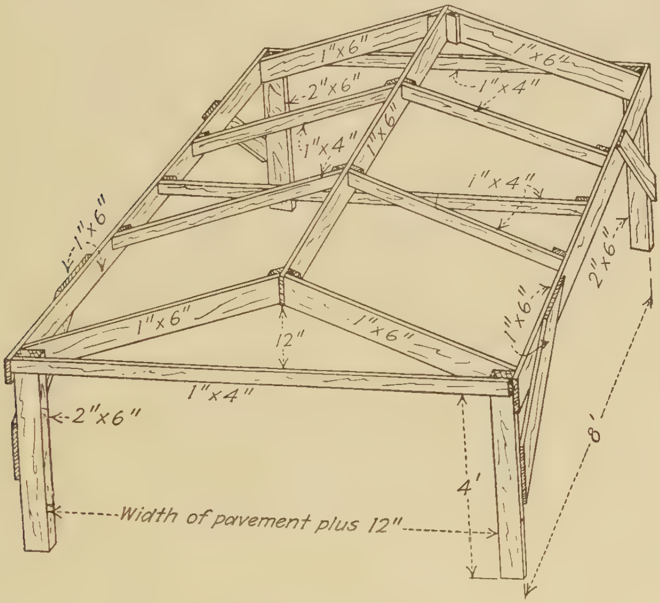


Fig. 32.—Frame for canvas cover for pavement.

mix as is practicable so that the finishing can be hastened and protection installed. This may be insulation or enclosure and heating. If the concrete is placed dry and at about 80° it can generally be finished and covered at temperatures of 40° down to freezing, before the heat has greatly dissipated. Straw held down with tarpaulin will meet the requirements. At freezing and lower tempera-

tures, enclosure and heating have to be substituted for insulation. The housing structure, because of the necessity of repeatedly moving it, has to be light in weight and in sections which can be carried ahead. Canvas on light timber frames is the usual construction. An example of frame construction is shown by Fig. 32; a more usual form omits the vertical posts. A common practice is simply to spread tarpaulins on trestles. Oil stoves, salamanders, or steam pipes are used for heating; they can be hung from the framework or set on bridges like finisher's bridges. The pavement behind the shelter should be covered with straw over which canvas is laid.

66. Examples of Winter Paving.—Practice in concrete paving in cold weather has been confined to the construction of remainder sections in the late fall to avoid carrying the work over into the following season. In effect it has been emergency work. Indeed, highway builders do not regard cold-weather paving in any other light and plan to avoid it as much as possible. These statements have to be remembered in explanation of the examples which follow.

In Minnesota, in 1925, on account of the unusually early fall and bad weather during October, several paving contracts which were scheduled for completion by Oct. 15 were not completed until early in November. As only a small section of pavement was left on each of these contracts, both the state and the contractors were anxious to complete the paving, the states' interest being the elimination of the detour as soon as possible, and the contractors' interest being to release their outfits for new contracts during the following season and also to release the retained percentages on the contracts.

On three contracts arrangements were therefore made with the contractor for the use of calcium chloride solution in the concrete mix, using a 2 per cent solution in the required amount which would be equivalent to 2 lb. of calcium chloride per square yard of pavement. The contractors also were required to cover the subgrade with straw as soon as the fine grading was completed to avoid

Plate IX.—Winter work on Ford Motor Company building, Kearney, N. J. Constructed in 1919–1920 by the Turner Construction Company, New York.

the possibility of laying concrete on a frozen subgrade. The pavement was covered with burlap as soon as possible after the surface was finished, and sufficient straw was placed over the burlap and slab to prevent freezing of the slab for a period of 10 days.

As a further precaution, the sand was heated with steam jets and the water was heated by the introduction of a homemade furnace in the pipe line leading to the mixer. With these precautions, concrete pavement was laid with satisfactory results, in spite of the fact that during the period of constructing the temperature reached a minimum of 10°, and frequently a temperature of 20°.

In order to determine the strength being obtained in the concrete slab under the method of construction and protection, sample beams were cast each day which beams were subjected to the same protection as that given the concrete slab. These beams were later tested for tensile strength and the pavement was opened when the concrete in the test beams showed the required strength. Under the conditions described, the pavement slab obtained sufficient strength to permit it to be opened for traffic at the end of 14 days.[1]

Wisconsin, in 1924, awarded a contract for approximately 9 miles of paving rather late in the season; so late in fact that there was only a bare possibility of its being completed before winter set in. Trouble arose over the transportation of materials and the job was still further delayed. Pouring on this job continued up to and including Nov. 26. The method of protecting the concrete from freezing was as follows:

At the end of each day's run, sufficient subgrade for the next day's run was covered with hay to prevent it from freezing. The next morning the final trimming was done, and concreting was resumed. A return bend coil of 2-in. pipe was placed in the pipe line and a fire was built on top of this. This took the chill out of the water. At the time this work was being done, the state was using the so-called

[1] O. M. Kipp, construction engineer, state highway department.

"sunshade" and a number of these were on the work. These sunshades were built up of ribs made out of 1 × 4 in. material, with sufficient arc so that they cleared the pavement by about 2½ ft. The ribs were covered with muslin. These frames were built in sections 12 ft. long. When work was closed down for the night, these sunshades were placed over the pavement and a lantern was hung in the center of each one. The joints where they came together were covered with marsh hay, and sufficient hay was thrown over the muslin to keep the heat of the lantern in. These lanterns were kept burning until the concrete had set sufficiently so that the frames could be removed and the pavement covered with a heavy coating of marsh hay. The only slabs that were touched at all with frost on this job were those poured during a time when no one thought of frost affecting the slab at all. As a matter of fact, the slabs had been laid 3 days before the cold weather set in. The last slab on this project was poured on Nov. 26, and from outward appearances no one could tell whether the work was done in the summer or late fall.[1]

Connecticut, in 1925, did not complete some of its concrete road work until well into December. The common practice during the latter part of the work was to build up the subgrade to the proper elevation with clean gravel. After being thoroughly rolled, it was covered with straw to prevent freezing. If there happened to be any frozen material on the subgrade it was dug out and replaced with gravel, in order that there should be no frozen material under the concrete. A solution of calcium chloride was used in the mixture and the water was heated, which ordinarily gave concrete of a temperature around 45°. As soon as finished, the concrete was covered with hay to a depth that would prevent freezing and travel was kept off the finished road for approximately 2 months.[2]

On 2,500-ft. remainder of concrete road work in Wisconsin, in 1919, the contractor employed the following method:

[1] F. M. Balsley, construction engineer, state highway department.

[2] E. C. Welden, Deputy State Highway Commissioner.

As soon as the concrete was hardened enough to prevent it from being injured by contact with a canvas cover, this was laid over it and from 6 in. to 1 ft. of straw placed on top. Care was taken to extend the layer of straw 2 ft. or more outside of forms to prevent freezing from the sides. When the temperature did not vary much from the freezing point this cover proved ample protection. During the last 3 days of work, however, temperatures close to zero prevailed and extra precautions had to be taken. In addition to heating the materials, added thickness was given the straw cover and over the straw a second canvas of heavier weight was laid and fastened down.[1]

In Pennsylvania on 1,000 ft. of pavement put down in 1919, the methods were as follows: To keep the subgrade in satisfactory condition to receive the concrete, four lines of ¾-in. steam pipe were strung along the subgrade and supplied with steam from a steam roller. These pipes were covered with straw and that in turn with canvas to confine the heat. This took out the little frost that had already gone into the subgrade and left it in good condition. A Hauck kerosene torch, having a 20-gal. fuel tank, about 12 ft. of ¾-in. rubber hose, and a 3-in. burner, was installed on the mixer. The tank was put under a pressure of about 85 lb. and the flames from the torch were directed into the discharge end of the mixer drum. An elbow at the end directed the flame so that it practically filled the drum and came in contact with the mix as the drum revolved. Cold water, and stone and sand containing frost, were turned into the drum with the cement and the batch mixed 1½ min. At the same time a test was made; the temperature of the outside air was 28° and the temperature of the mixture when the batch was discharged was 80°. A thermometer placed in the concrete after it was dumped on the subgrade showed a temperature of 58°. A 1-in. hole was punched in the slab, 3 in. deep and 2 ft. from the side of the road, the thermometer was inserted and covered with a piece of joint filler raised ¾ in. from the slab. The temperature was 52° 1

[1] Bossert Coal Company, contractors.

hour after the concrete had been placed; after 2 hours 50°; after 3 hours 45°; after 4 hours 43°, at which time the day's work was completed and covered up. During this period the concrete was exposed to the weather to allow finishing. After the last reading of the thermometer the concrete was covered with canvas supported on wooden trestles which came close to the surface of the concrete on the edges and raised about 18 in. from it at the center. The edges of the canvas were sealed to the surrounding ground to exclude cold and prevent freezing of the concrete near the edges, and eight ordinary lanterns were suspended at about 10-ft. intervals along the center of the cover. These were kept burning all night. On the night that the test had been made the air temperature went down to 8° above zero. On the following morning it was found that the temperature underneath the canvas was 40° and a later inspection showed no evidence of freezing or unequal contraction.

The method added very little to the cost of placing the concrete, as the mixer was run only about 1/4 min. longer than ordinarily and pumping the air tank required about one-half of one man's time. A very good output could have been obtained had it been possible to keep the water supply and other features working satisfactorily. It was found almost impossible to keep the water lines open and free from freezing, even while working under full head. Two days of rain, then a sudden drop in the temperature to 7°, with such high winds that it was impossible to keep the men at work, compelled a shutdown when within 250 ft. of the finish. The subgrade became frozen to a depth of 18 in. and the steam pipe system was unable to overcome the cold, so further operations were impossible.[1]

67. Road Bridges.—Bridge construction for roads is important to notice chiefly to indicate control methods. These, as worked out by the Michigan highway department, which builds regularly 12 to 16 bridges every winter, are as follows: In general, the department does not hold that winter construction is so desirable as construction in warm

[1] Field, Barker & Underwood, contractors.

weather, but it considers that it should be undertaken without hesitation whenever time gained in putting the road into service equals in value the extra cost of doing work in winter. For concrete, this extra cost runs from $3 to $6 a cubic yard. Often, however, contractors bid as low in winter as in summer, the advantage of keeping their organizations intact and their equipment earning rental making up for the extra cost of winter protection.

The specifications for winter concrete are, in all qualifications, those for warm-weather concrete plus requirements for heating, housing, and curing. Concerning mixing, the specifications state that:

> For any concrete which is mixed while the temperature of the air is lower than 40° F., the aggregates or mixing water, or both shall be heated so that the temperature of the concrete, at the time of placing in the forms, shall not be less than 50° F. and not more than 75° F. In no case shall either mixing water or aggregates be heated to a temperature higher than 120° F. Aggregates shall be heated by steam lines so arranged as to insure the uniform and thorough heating of the entire mass. Aggregates containing frost or frozen or hardened lumps shall not be used.

The limiting temperature of 120° was adopted under the impression that greater heat would injure the cement. Later experience and all evidence have shown that no such injury results and now in the field considerably higher temperatures of water and aggregates are permitted. It is likely that new specifications will put a higher limit on temperatures.

Contractors' procedure and plant for heating materials naturally vary in detail but common bridge work exhibits enough similarity in structure type and volume of work to have developed common practices to a considerable extent.

The common method of heating aggregates is to pile them over perforated steam-pipe grids. For heating water, a steam jet in the tank or a coil in a large salamander are most common. Both require pumping and the latter involves the hazard of burning out the coils in case of pump

REPORT ON CASTING CONCRETE

Covering Casting of N. Abut. Girder Unit #11 Bridge File No. 140901

Date 1-29-1927 Time From 8-45 to 11-50

From 12-20 to 3-00

From to

Quantity of Conc. 34.5 Cu.Yds. Mix Used 1.0-2.7-4.3 Grade B

Cement - Estimated Amt. 43.12 bbl. Actual Amt. Used 42.5 bbl.

Consistency 2½ to 3"

Materials Proportioned by Cu. ft. box + templet wheelbarrows

Transported to Mixer by Wheelbarrows

Concrete from Mixer to Forms by Track cars and chutes

Size and Type of Mixer 2-bag drum Lansing Peserve Mixer one-bag tilter

Force Employed 1-14 + contractor

Weather Cloudy Temperature av 34°

Notes on Forms, Bracing, Tying

Sheeting 2½ T+G. Studs 2x6 spaced 2' + capped with a 2x6s waling double 2x6s Three wales with a max. spacing of 2½' Williams ½" rods maximum spacing 4' wooden spreaders between rods Double 2x6s from top wale to bank max. spacing 7' 2x6s middle wale to bank max. spacing 10 ft. Short 2x6s bottom wale to bank max. spacing 5'

Notes on Steel Spacing and Support

Steel spacing very good. Supported on chains and 2x6s

Difficulties none

Shutdowns noon only

For Winter Concreting Give Temperatures Below

Time	9	10	11	11-50	12-30	1	1-30	2	2-30	3	Avg
Outside Air	32	33	34	34	34	34	34	34	34	34	33.7
Inside Housing	32	50	50	50	48	48	48	48	48	48	47
Mixing Water	110	110	112	112	114	112	110	111	114	110	111
Fine Aggregate	72	80	86	88	90	90	92	90	90	90	86.8
Coarse Aggregate	64	66	70	68	72	72	70	70	72	72	69.6
Conc. in Forms	64	70	70	70	72	72	70	69	69	70	69.6

Method of Heating Materials

Perforated steam piping

Method of Heating Housing

3 Stoves, 2 coke burning Salamanders Housing O K

Temp. at 4 P.M. 60

Submitted ______ Approved ______ Noted ______

Inspector Project Eng. Res. Eng.

CEF-165

Fig. 33.—Method of reporting winter concreting on Michigan road bridges.

stoppage. In case water can be drawn directly from the stream below, good success has been had with steam ejectors, or siphons, which both pump and heat the water. The temperatures to which materials are heated are fairly indicated in Table V, which records 16 separate runs, and also in the record (Fig. 33). Carriage to the mixers is usually by wheelbarrow. The mixers are commonly one- or two-bag machines and the batch is mixed 1½ min.

Table V.—Records of Materials and Concrete Temperatures in 16 Days' Runs on Winter Bridge Work

Number	Date	Volume, cubic yards	Air, degrees Fahrenheit	Water, degrees Fahrenheit	Fine, degrees Fahrenheit	Coarse, degrees Fahrenheit	In forms, degrees Fahrenheit
1	Nov. 23	11.4	27	120	40	35	65
2	Nov. 30	11.4	33	120	65	50	57
3	Dec. 3	7.8	30	120	48	35	68
4	Dec. 10	7.8	31	110	105	80	80
5	Dec. 13	3.9	20	120	95	90	75
6	Dec. 21	3.9	38	120	75	70	75
7	Jan. 4	23	36	120	75	60	72
8	Jan. 5	21.4	24	120	68	40	68
9	Jan. 8	12.7	19	120	75	45	72
10	Jan. 12	12.7	30	120	75	50	65
11	Jan. 17	3.4	23	115	75	50	74
12	Jan. 21	3.4	27	115	75	42	74
13	Jan. 21	7.7	..	120	75	45	66
14	Jan. 24	7.7	..	120	75	45	67
15	Jan. 28	21.5	33	120	75	40	70
16	Jan. 31	22.2	18	110	55	45	65

Carriage to the forms is by wheelbarrows, hand cart, or small tip cars on industrial truck. The distances are usually short. The table indicates temperatures at which the concrete goes into the forms.

For protecting the concrete in place, the specifications require housing and heating. Housing requirements are:

All concrete which is cast while the air temperature is at or below 35° shall be protected from freezing during casting and for a period of 14 days thereafter by means of a suitable housing

of lumber, tar paper, canvas, burlap or other satisfactory material, and artificial heat shall be provided to maintain the temperature inside the housing at not less than 40° during the casting and for 3 days following the casting at not less than 50° during the succeeding 7 days.

When the air temperature at the time of casting is above 35° but with a possibility of dropping below that point during a period of 14 days after casting, the contractor shall supply sufficient lumber, canvas, tar paper, burlap, straw, or other approved material, and artificial heat, if necessary, to protect the concrete and keep the temperature of the concrete at all times during that period above 35° F.

Several forms of housing are shown by Figs. 34 to 36. Generally, the covering is canvas held up by staging. Tar paper on timber frames or completely board-sheathed houses are also used. If the bridge is small the housing

FIG. 34.—Housing for concrete pedestals for Michigan road bridge.

may cover the whole structure down to the ground. On larger operations, only the portion being concreted is housed. The idea is to get a tight enclosure large enough to work in conveniently, without much regard to kind, and then keep it warm. The requirements for heating in addition to those first stated are:

Artificial heat shall be provided by steam lines, salamanders, or stoves. Salamanders or stoves shall be used only if placed at a sufficient distance from the fresh concrete to insure against too

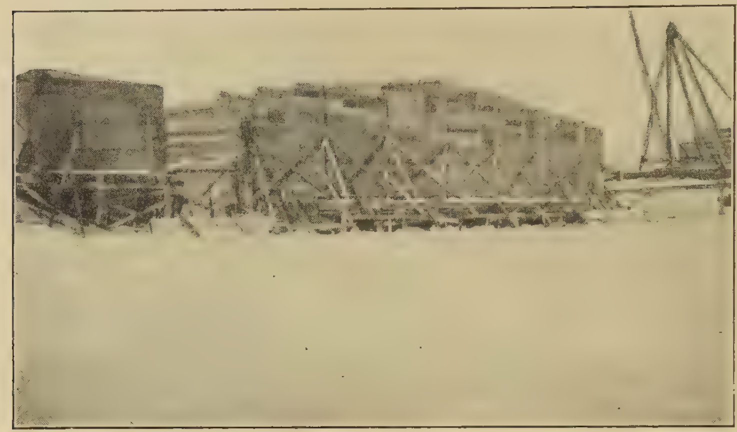


Fig. 35.—Wood housing for bridge abutment.

rapid or uneven drying and shrinkage of the concrete; and the arrangement of such heating equipment shall, in all cases, be

Fig. 36.—Tar paper housing for bridge abutment.

subject to the approval of the engineer, who may require the use of steam lines if he considers other equipment unsatisfactory.

Whenever artificial heat is employed for protection of concrete, adequate provisions shall be made for maintaining a high moisture content in the surrounding air as required under Curing of Concrete. The required finishing of concrete surfaces shall be conducted during the 14-day period. Housing shall be left in place and artificial heat shall be continued until such finishing is completed.

In practice, steam lines are preferred for heating enclosures. With a perforated pipe, they give a moist air. Salamanders give a dry heat and, in the small enclosures, foul the air. On, say, a 40-ft. bridge a 20-hp. boiler will give all the steam required for heating materials and the housing. In putting in footings, steam jets are also used to keep the water warm and to prevent scale ice; very little steam is required. The specifications are:

In case a footing will be completely covered by water to a depth of not less than 6 in. immediately after it is cast, no provision need be made for enclosing it but artificial heat shall be supplied, if necessary, to keep the temperature of the surrounding water at not less than 35° F. and this temperature shall be maintained for not less than 10 days after casting.

Whenever any portion of the concrete work is left during freezing weather with keyways, anchor bolt wells or other depressions on horizontal surfaces exposed, adequate provisions shall be made to prevent accumulation and freezing of water in such depressions.

Curing is given particular attention in the specifications:

In case the structure or any portion thereof is enclosed and artificial heat provided for protection, the requirement of moisture for curing shall not be waived. The required damp sand covering shall be placed on floor slabs and wearing surfaces but the canvas or burlap covering for girders, etc., shall be omitted. If steam lines are used for heating, the pipe connections shall be left loose to permit the escape into the housing of sufficient steam to maintain a moist atmosphere at all times. If stoves or salamanders are used, vessels containing water shall be kept on the stoves or salamanders for the same purpose.

Control of work in winter, as at other times, is kept through inspectors and the engineers in charge. A daily report is made to headquarters, using the form shown by Fig. 33. This is a report from an actual day's run, and it indicates the close check kept on all items. With this control, frosted concrete has been of rare occurrence and then only a shallow surface injury.

CHAPTER X

SPECIAL CONCRETE AND CEMENTS FOR WINTER WORK

Cold has a positive effect on concrete. It retards or can absolutely check setting and hardening. Concrete is again exceptional among major construction materials in the property that setting and hardening develop heat which, in a measure, resists frost action. The reactions between cold and the heat generated in setting and hardening range between wide limits. Concrete construction is, therefore, the major problem of the winter builder; it offers his chief hazard and demands his best technical skill. If knowledge and skill are rigidly applied, concrete construction can be carried on at extremely low temperatures with full confidence of good results. There can be no lack or neglect, however, without extreme hazard. Concrete must be protected from chilling either by its own generation of heat or by being artificially kept warm until it has set and gained a safe strength.

68. Special Mixes.—To hasten the gain in strength and, therefore, to reduce the period for which concrete must be kept warm and given particular care, special concrete mixes are available and are being used. The chief of these are (1) high alumina cement mixes, (2) special portland cement mixes, (3) high early-strength mixes of standard portland cement, and (4) mixes to which have been added accelerators, themselves resistant to freezing. A comparison of alumina and special portland cements made by the Kansas City Testing Laboratory is given in Table VI.

69. Alumina Cement.—There are various brands of alumina cement. These have given a variety of results and much work needs still to be done in the line of control and standardization to make users entirely sure of them as a

class. The winter builder should investigate the brand before using it. In general, high alumina cements set and harden much more rapidly than does standard portland cement and there is a correspondingly intensified heat development. Broadly, concretes of special alumina cements have a strength in 24 hours equal to the strength of ordinary portland cement concrete in 28 days. As

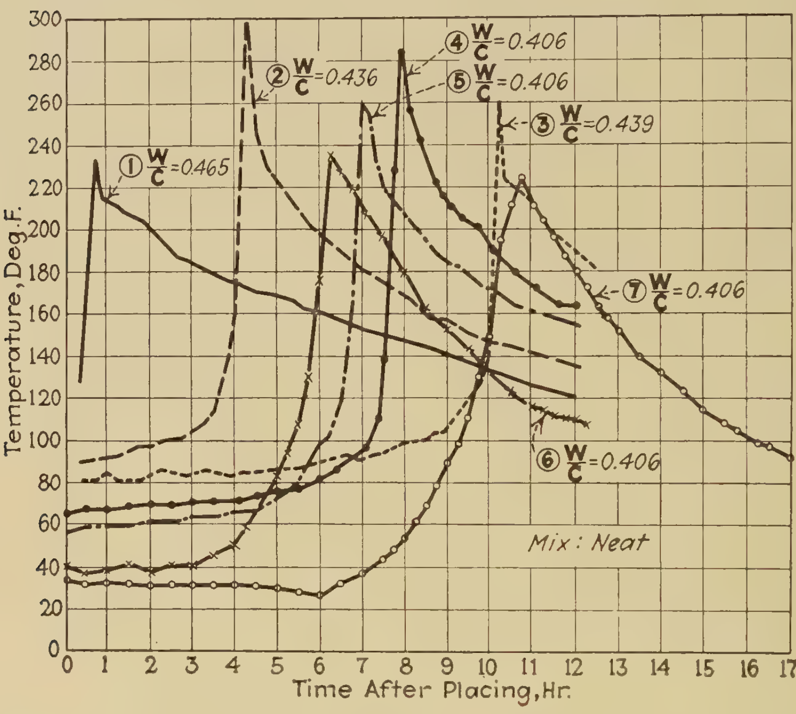


FIG. 37.—Temperature curves of neat alumina cement using various initial temperatures.

indicating the quick rise in temperature, the graphs from tests made at the University of Minnesota, given in Figs. 37 to 39, may be consulted. The early strength reduces the period during which the concrete has to be kept warm and the high heat development increases the counteraction against frost. In using alumina cement concretes, and particularly in their curing, variations from practices with

portland cement are required; the user has to bear this fact very firmly in mind when resort is made to alumina cement concretes. The use of alumina cement specifically for cold-weather construction has been limited compared

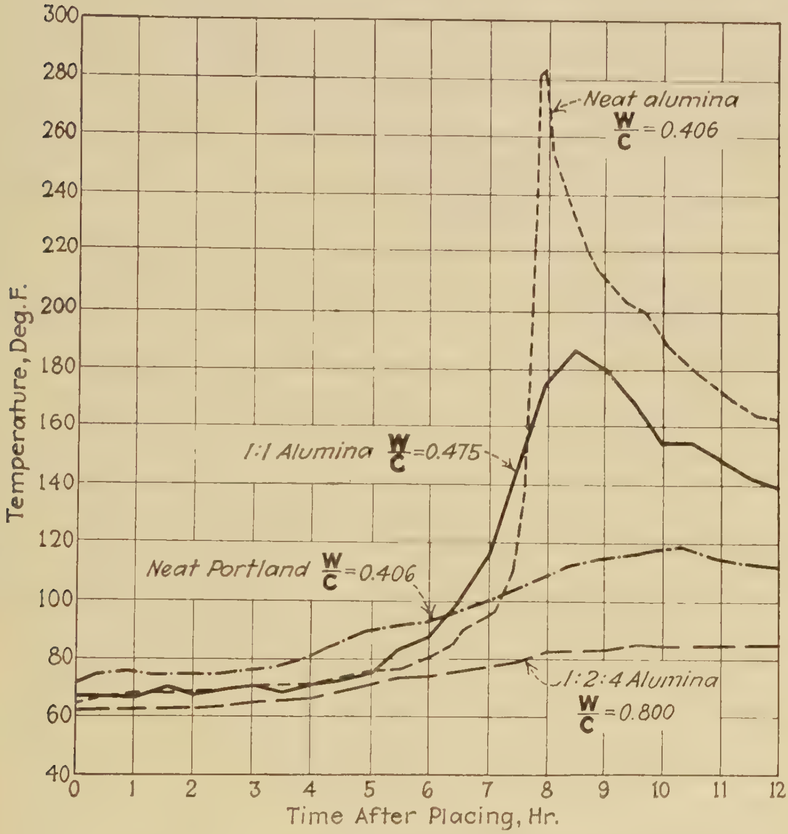


FIG. 38.—Temperature curves of various mixes using the same initial temperature.

with the use of portland cement but the results have been generally good. In general, it may be concluded:

1. As alumina cement concrete gains strength and generates heat more quickly than does standard portland cement concrete, it decreases the time for which it is necessary to keep the concrete in place warm.

2. Users need to become familiar with the characteristics in setting and curing when they undertake the use of high alumina cement concrete.

Examples of the use of alumina cement concrete in road construction are given in Sec. 62. It has been more frequently used in winter building and reports from half a score of operations indicate that, in moderately cold weather, high alumina cement concrete needs only light insulation for not to exceed 24 hours. It is urged again that the user should investigate the brand and inform him-

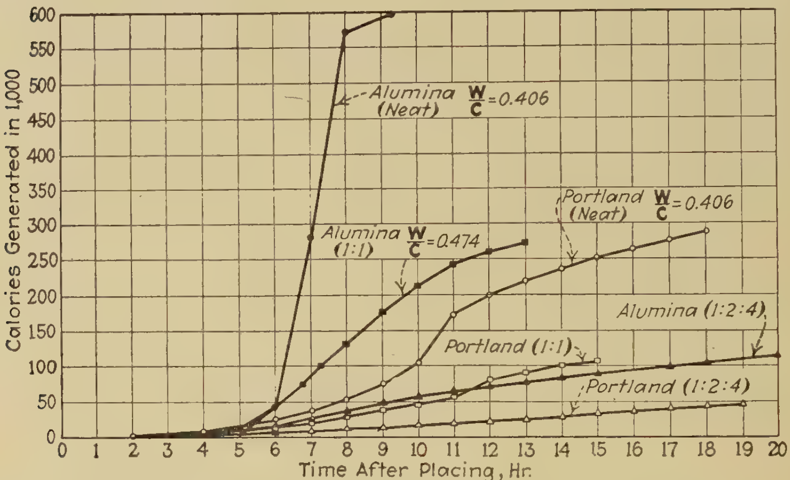


FIG. 39.—Comparison of heat generated by various mixes of alumina and portland cements.

self of the precautions to be taken in handling the new material.

70. Special Portland Cements.—The special quick-setting portland cements are portland cements in which there is a slight variation in the normal mix, with unusually fine grinding, and to which some agent has been added to produce quicker hardening without materially affecting the setting time. They are made widely in Germany and there are several brands produced in the United States. Some of these special portland cements give in 24 hours a concrete equal in strength to 28-day concrete of standard portland

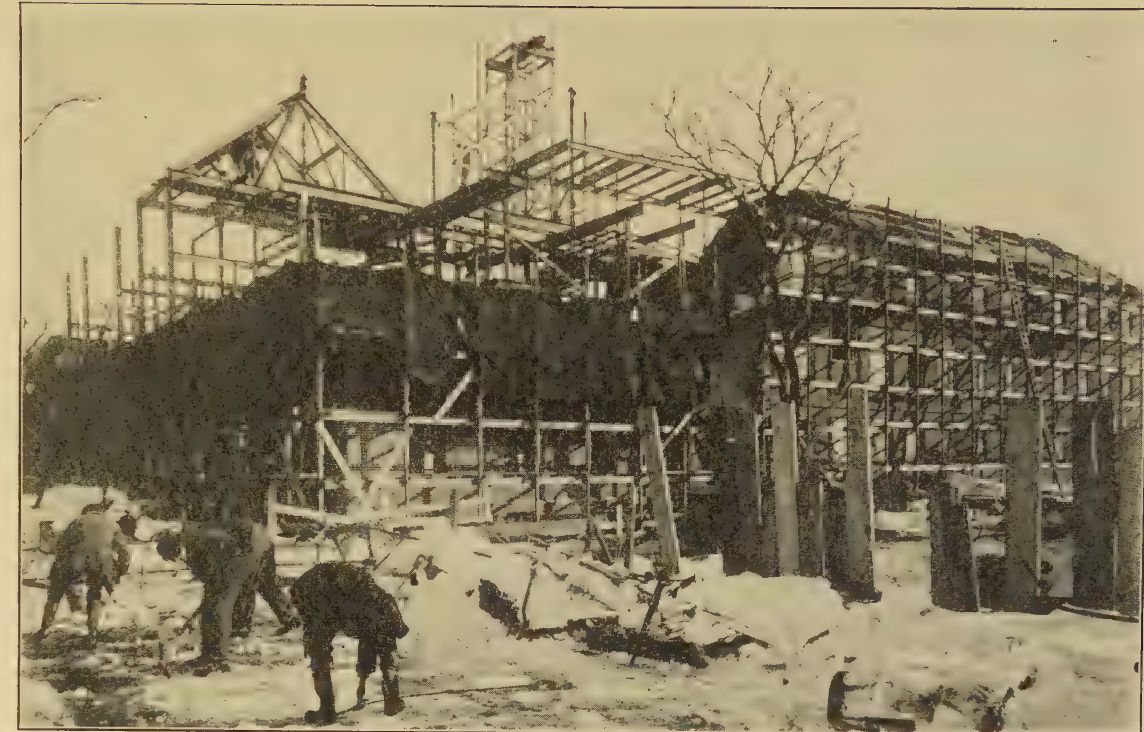


PLATE X.—A winter task, cleaning away snow and ice.

Dormatory at Cambridge, Mass., constructed in winter cf 1925–1926 by the George A. Fuller Company, New York.

cement. Their heat development is indicated by some of the tests reported in a succeeding section.

71. High Early-strength Mixes.—By special proportioning and mixing, a concrete can be made of standard portland cement which in 3 days has the strength of normal mixes at 28 days. The processes are: decrease the water, increase the mixing time, increase the cement, add calcium chloride, keep the placed concrete damp and warm (70°). A care in production is involved in these processes which ordinary field control of concrete has not practiced. With this care, high early-strength concrete is practicable with any reasonably well-equipped and well-organized mixing crew. Like high alumina cement concretes, high early-strength portland cement concretes must be kept warm until strength is acquired; their activity, compared with standard mixes, merely cuts down the period of necessary protection. There has been no extensive use of high early-strength concrete specifically for cold-weather construction.

72. Mixes with Admixtures.—Admixtures have an older standing as aids in cold-weather concreting than have special concretes or special mixes. In using admixtures, two requirements have to be adhered to: (1) The substance must lower the freezing point of the mixing water and (2) it must accelerate the setting and hardening of the concrete. Of the various available substances which meet both requirements, calcium chloride is the most practicable because of its general availability and the familiarity of the workmen with it. The amounts of calcium chloride which may be used with advantage vary with the chlorine content and with the brand of cement; it is wise practice, therefore, to make up trial batches under the conditions and note the rate of hardening and the effect on strength. In general, 2 to 4 per cent of the weight of the cement is about the safe percentage; more is likely to decrease the strength. A solution and not dry powder should be used; about 4½ pt. of saturated solution per sack of cement is equivalent to 3 per cent of the cement by weight. With considerable experimentation and experience to reason from, the conclusions of several investigators are:

1. Dependence should not be placed on the lowered freezing point of the mixing water.

2. In cold weather it is much wiser to heat the concrete, furnish proper protection, and supply artificial heat than to depend alone on an admixture.

3. Admixtures by reducing the freezing temperature somewhat give more time in which to instal protective covering and supply artificial heat.

Examples of the use of calcium chloride are given in succeeding chapters.

73. Tests of Heat Development.—Significant determinations of heat development in concrete of the various cements

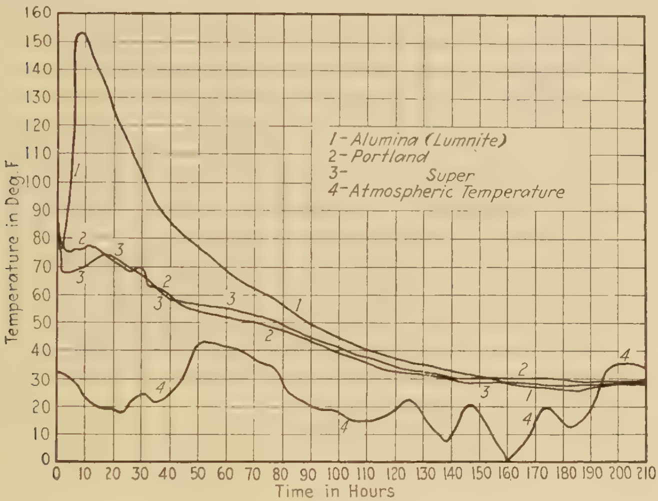


FIG. 40.—Comparative heat development of three kinds of concrete.

considered have been made at both the Michigan State College and at the University of Minnesota.

The tests reported by the Michigan State College included portland cement, Peerless super cement, and lumnite cement. Thermometers were placed in 2 × 3 × 2 ft. blocks insulated by 1½-in. wood forms and on top and bottom, one near the top, one near one side, and one at the center. Figure 40 is typical of the ten sets of curves secured in these tests. The general conclusions from the tests were:

Lumnite Cement.—The average temperature for the first 144 hours was approximately 84° F. At the end of this period the freezing point was reached. The Lumnite cement has a very distinct advantage over other cements for winter concreting, in that the rapid chemical action causes high temperature which prevents freezing until such a stage of hydration is reached that there is not sufficient moisture left to form ice crystals.

Peerless Super Cement.—Twenty-nine hours elapsed before the temperature reached 70° F., at which time the material would have attained approximately 68 per cent of its strength; and a total period of 140 hours elapsed before the freezing point was reached. This gave a setting period which would place this cement well beyond danger of frost action when poured under such conditions as existed at the time this test was made.

Portland Cement.—The time required for this concrete to cool to the freezing point was 130 hours, the average temperature during this period being 54°. The temperature at each 10-hour interval was:

Hours	10	20	30	40	50	60	70	80	90	100	110	120	130
Degrees temperature	71	75	76	71	64	59	54	61	46	42	40	37	35

The average temperature for each day until the freezing point was reached was as follows:

Degrees Fahrenheit			
First day	Second day	Third day	Fourth day
73	70	59	39

It can therefore be concluded that under weather conditions such as existed during the time these tests were made, portland cement concrete, if mixed at a temperature of from 80 to 90° and placed in heavy wood forms, and the surface properly covered, will set sufficiently strong to be past danger due of freezing if no other provision is made for applying heat to the material. It must be remembered, however, that this applies to heavy walls and not to light

sections and floor slabs. For full details of the tests, the reader is referred to *Bulletin* 8, Engineering Experiment Station, Michigan State College, Lansing, Mich.

The University of Minnesota tests were made on 6 × 12 in. cylinders with very elaborate provisions for insulating the specimens, generating initial temperatures and measuring temperatures and the heat developed. The results, as reported by Prof. A. A. Jakkula, are given in the charts in Figs. 37, 38, and 39. The tests were considered to support the following conclusions:

1. When the specimens are made of neat alumina cement of average consistency and are confined so that the heat generated cannot escape, a temperature above the boiling point of water may be expected, due to the chemical action of setting and hardening.
2. Decrease in the richness of the mix reduces the temperature rise.
3. Figure 38 indicates that the alumina cement specimen reached a temperature four times that of a similar portland cement specimen.
4. The rise in temperature with alumina cement takes place very suddenly. In every instance, a rise of over 100° F. took place in approximately 15 min.
5. A high initial temperature causes quick setting of an alumina cement mix.
6. In all cases, for the same mix and the same water-cement ratio, the specimens composed of alumina cement generated over twice as much heat as similar specimens of portland cement.
7. At initial temperatures below 80° F., the temperature of a concrete using alumina cement will start to rise in about 5 hours.

74. Summary.—Especial consideration has been given to these special cements and special mixes because it is believed that they are destined to play a greater part in winter concrete construction than they have yet been allotted in practice. At present, one or more of the following objections applies to all of them: (1) high cost, (2) special pro-

cedure required, (3) limited range of effectiveness, and (4) uncertainty of their behavior. As use develops experience and becomes more common, the development of a special concrete is possible which will make this material virtually independent of frost conditions.

Table VI.—Characteristics of Various Hydraulic Cements

	Plain portland cement	Quick-hardening portland cement	High alumina cement
Chemical composition, per cent			
Lime (CaO)	61.91	65.27	39.91
Alumina (Al_2O_3)	7.92	7.10	39.53
Iron oxide (Fe_2O_3)	2.40	2.12	15.41
Silica (SiO_2)	20.65	21.32	2.59
Magnesia (MgO)	3.54	1.40	0.73
Sulphur (SO_3)	1.35	1.85	0.21
Alkalies, chlorides, etc	0.5		
Tensile strength, pounds per square inch			
1 to 3 sand briquets—			
24 hours	0	330	464
7 days	250	430	537
28 days	400	538	561
Compressive strength, pounds per square inch			
1 to 3 sand cylinders—			
24 hours	0	3,755	4,725
7 days	2,500	9,891	4,985
28 days	4,500	12,212	5,004
1 to 2 to 4 concrete—			
24 hours	400	2,130	2,865
3 days	1,200	3,457	3,542
28 days	3,800	5,690	3,891
Fineness, per cent			
Passing 200-mesh	85	95	97.6

CHAPTER XI

WINTER HEATING OF CONCRETE MATERIALS AND MIX

Heat is requisite for the setting and hardening of concrete, and, in hardening, concrete develops heat. Heat conservation to the extent necessary for continued setting and hardening until strength is attained to carry at least construction loads is, then, the essential task of winter concreting. With standard portland cement, test and experience indicate that the temperature should be kept at not less than 50 to 60° for 5 days. This assertion is made despite the fact that construction records present many examples of structures which have set up and hardened and are apparently structurally sound, in which the curing temperatures did not exceed 40 to 50°. The 5-day period gives concrete a strength at which heating, or protection from cold, can ordinarily, in construction, be discontinued. At low temperatures, concrete thereafter does not continue to gain strength in a normal manner—it cures and hardens and becomes strong slowly. There must, therefore, in winter be especial care in removing forms and in reposting floor slabs and beams. Cold weather, then, as it has to be regarded in concrete construction, is not confined to actual frost, but to any degree of cold less, say, than 50°.

75. Heated Concrete.—The most common way of producing heated concrete is to preheat the materials. On occasion, heating in the mixer is undertaken, but most often mixer heating is supplementary to preheating the aggregates and water. The use of preheated materials predicates that the mixing operation proper shall preferably be protected from the cold. The consideration of heating concrete materials, then, will include housing the mixers and

the proportioning and charging space, and often the mixer discharging space.

In the matter of heating materials, practice presents two schools of thinking. With one, no more heating is undertaken of the sand and of the coarse aggregate than is necessary to remove the frost and prevent congealed masses or lumps from going into the mixer. These materials, it is held, are so hard to heat and hold their heat so poorly that it is economy to put the heat into the water and depend on it to make the mix warm. The second school holds that the aggregates, as well as the water, should be given a temperature. It is argued that the water alone, perhaps no more than 20 per cent of the volume, cannot carry enough heat to warm the mix adequately for really cold-weather operations. A decision between the two will depend probably on related conditions of mass, exposure, temperature, and structural hazard. The objective is to get concrete into the forms and there hold it at a temperature which will keep it active until it has enough strength to eliminate the frost hazard. Records from practice of concrete temperatures at the mixer range from 40 to 125°. Ordinarily, a temperature of 80 to 90° is necessary at the mixer to insure a temperature of 60 to 70° in the forms. The subject is considered further in Chap. XII. Succeeding chapters also describe heating equipment and methods employed on specific operations there discussed. These special installations should be studied in connection with the summary of general methods which follows.

76. Heating Open-stock Piles.—Open-stock pile heating is employed chiefly where the mixer is charged by barrows or hand carts. The common heating devices are: (1) furnaces over which the sand and coarse aggregate are shoveled for heating; (2) steam jets inserted in the stock piles; and (3) steam-pipe grills over which the materials are stocked. In rare instances, rotary driers have been employed. For considerable outputs, these devices have to be faster than for ordinary drying purposes and of large size which makes the investment large. Their output

too must be used as produced, continuously; they provide no storage of heated stock. As yet, mechanical heaters have not been developed to command attention by concrete builders.

Furnaces, generally speaking, are limited to small operations. Ordinarily, they are of job production; an iron pipe with an improvised chimney at one end and wood fires inside is common construction. Several units can be fitted out according to the size of the operation. In isolated operations, a masonry furnace is practicable. On dam construction in Colorado[1] an open-top masonry furnace 10 ft. wide, 20 ft. long, and 30 in. high was constructed with I-beams across the top, 400 ft. of 1-in. pipe grill on these and 3⁄16-in. boiler plate on the grill. A wood fire was kept going in the furnace, the water was passed through the pipe grill, and the aggregates were spread on the sheet-iron top. The mixer, 9 cu. ft., was charged with wheelbarrows and turned out concrete at 80°. Job conditions and available material will suggest other forms of improvised furnaces. With furnace heating, two conditions have to be observed:

1. Constant replacement piling cold material and removing warm material, and
2. Careful watching to make sure that the aggregate particles are not injured by overheating.

Heating with steam jets serves a wider range of demands than does furnace heating. Overheating is not possible and no shifting of stock is required; instead the steam jets are shifted. A good form of jet is a 1- to 1½-in. pipe 6 ft. long drawn to a closed point at one end and fitted for hose connection at the other end. Staggered perforations, 3⁄16- to ¼-in. holes, should be provided 1½ ft. apart. A hose connects the jet pipe with the steam line. The jets are pushed into the piles when and where needed, and steam is turned on as long as it is required. When taking from stock, a good arrangement is two jets in the stone pile and one jet in the sand pile just where the material is being taken away. For thawing and general heating, the jets

[1] Lake Humphreys, Carl A. Gould, Denver, engineer.

are placed, kept in place, and shifted as required. In all steam-jet heating, effectiveness is gained by covering the stock piles with tarpaulins which can be pulled aside for

FIG. 41.—Tarpaulin covered stock pile heated by steam jets.

restocking. Figure 41 shows tarpaulin-covered stock piles heated by steam jets.

Pipe grills are more elaborate heating units for larger storage than is considered for furnace or steam-jet heating.

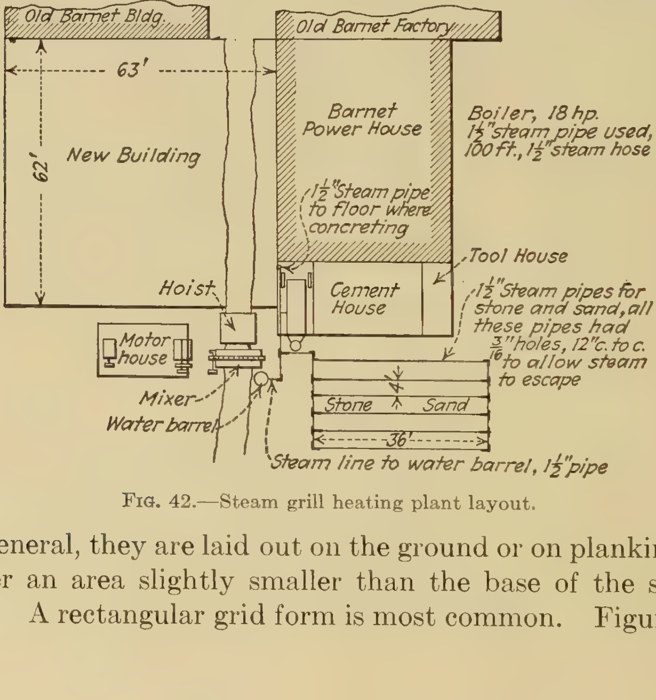


FIG. 42.—Steam grill heating plant layout.

In general, they are laid out on the ground or on planking to cover an area slightly smaller than the base of the stock pile. A rectangular grid form is most common. Figure 42

is an example.[1] The practice for a large operation of this company runs about as follows: A 50-hp. boiler carrying from 50 to 60 lb. of steam is necessary; on smaller operations like that shown in Fig. 42 an 18- to 25-hp. unit will serve at 35 lb. Generally, on any considerable building, a boiler of less than 50 hp. has to be pushed hard to heat stock piles and water and to give steam to floor lines for cleaning and heating forms. For heating aggregates, the grill is made up of 1½-in. pipes spaced 4 ft. apart and perforated with ⅜- to ¼-in. holes staggered every 18 in. In places where sand clogs the holes, hacksaw slots have met the difficulty. It is required that sand and stone have a temperature of 35 to 50° and water a temperature of 100 to 150°, and the heating units are made large enough to get these temperatures with the outputs planned.

Lack of capacity is the prevailing error in heating with grills; grill area and steam pressure are made too small and the time allowed for heating is too short. In general:

1. Spread the material over the grill uniformly a few feet deep; do not heap it in a cone-shaped pile.
2. Cover the pile with tarpaulin at night, and at whatever other times it is practicable.
3. Provide enough boiler pressure and capacity continuously to give good strong jets from the pipe perforations.
4. Allow 24 hours for heating each day's draw-off of material for concrete.

77. Heating in Open Bins.—Open-top bin heating is virtually an application of the steam grill system; the grill is laid on the sides and bottoms of the bins. As the heat is confined and insulated by the bin walls, its utilization is more complete than in open stockpiles. Otherwise, the requirements for grill heating in stockpiles apply to grill heating in bins, even to the tarpaulin covering at practicable times. Examples best give prevailing practice in open-bin heating.

A diagram of a heating plant notable for its full housing, employed on bridge-pier construction in Alberta, Can., is

[1] Turner Construction Company, New York.

given by Fig. 43. The aggregate heating unit consisted of 13 parallel chutes which were filled and emptied in rotation. Each chute was 3 ft. wide, 16 in. deep, and 24 ft. long and had in the bottom a close grid of 1¼-in. steam pipes provided with valves for heat regulation. The chutes were filled at the top by shoveling from stockpile and emptied at the bottom by gating into wheelbarrows. A chuteful was heated in about 30 min. The complete housing of all operations is indicated. The temperature of each batch as it left the mixers (three 1-cu. yd. machines) was tested by

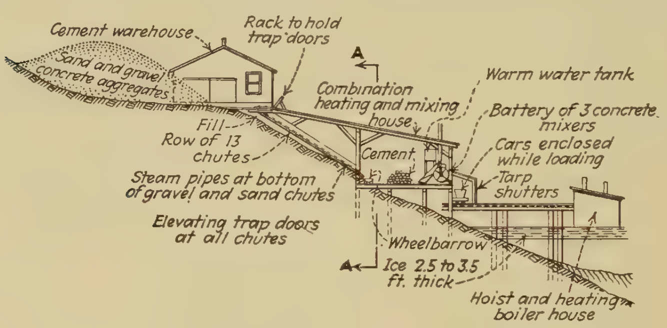


FIG. 43.—Arrangement for heating aggregates in chutes.

bath thermometers; this was done largely to keep a check on the heating. The construction was by force account.[1]

At the New York Edison 14th St. Power Plant in New York City the aggregate bins shown by Fig. 44 were heated by rows of perforated ¾-in. steam pipe, some 5,100 ft., running lengthwise on all inside walls of the *W*. A 125-hp. boiler furnished steam. A similar heating arrangement was used in the mixer charging bins.[2]

In these two examples are shown the extremes in practice: (1) rapid heating in small volumes, virtually continuous heating, and (2) slow heating in large volumes, several days being required for material to pass through the bins.

78. Heating in Housed Bins.—Heating in housed bins is a steam-grill process exactly similar to that in open-top

[1] Grand Trunk Pacific Railway, A. M. Bouillon, engineer in charge.

[2] Kenn-Well Contracting Company, New York.

bins except (1) the tops of the bins are partly or temporarily roofed in, or (2) the bin structure is completely enclosed in a housing.

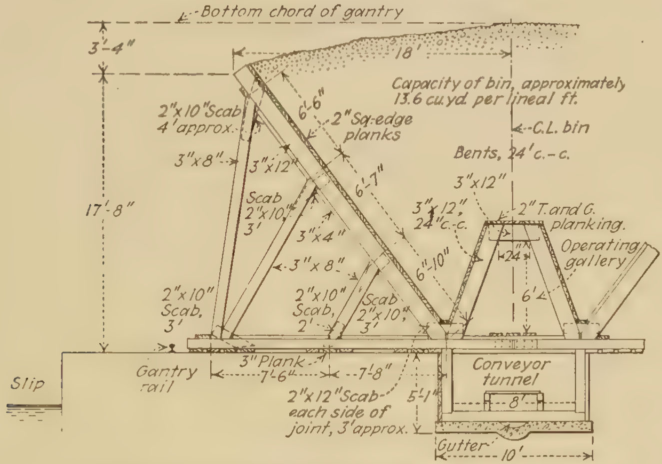


Fig. 44.—Grill-lined open bin for heating aggregates.

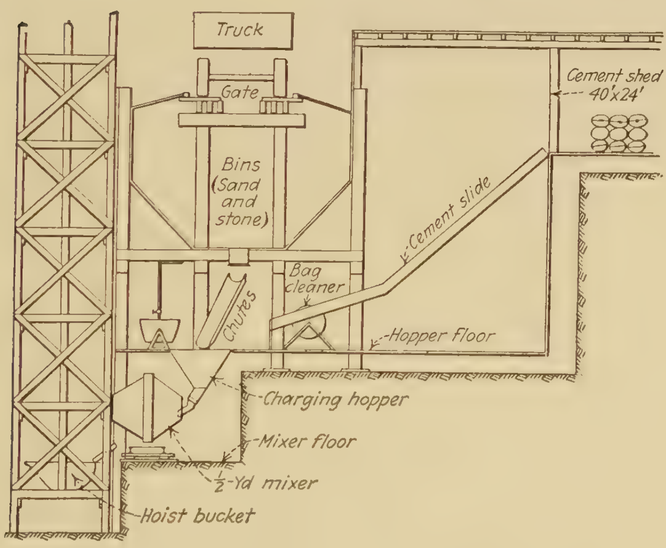


Fig. 45.—Grill heated covered aggregate bin.

An example of partly roofed bin is given in Fig. 45. This arrangement was employed in building construction: The

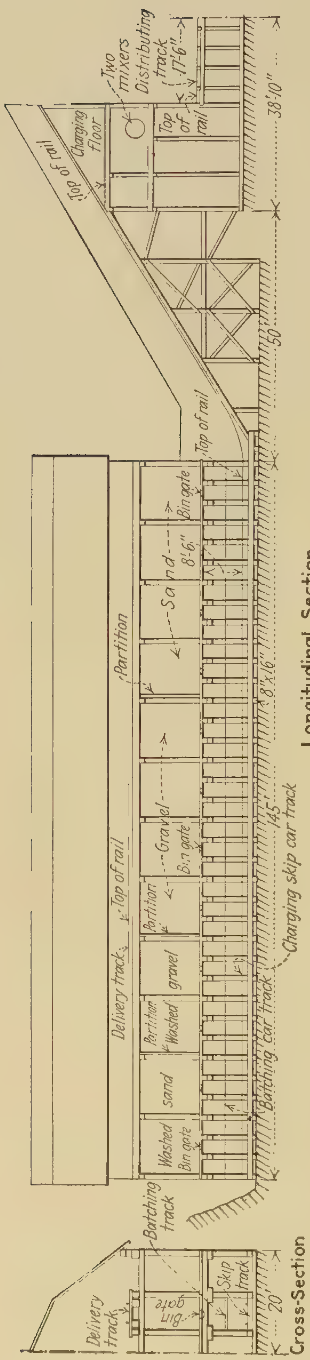


FIG. 46.—Heating house for aggregate in bins.

grill on sides and slopes was perforated pipe; a 35-hp. boiler furnished steam. It was found possible to give the materials 150° temperature.[1] Often the arrangement is the more simple one of a tarpaulin covering spread over the bin top at night and at such times during the day as bin filling leaves any considerable available time.

A notable example of complete enclosure is furnished by the Gulf Island dam on the Androscoggin River in Maine, 1925–1926, where about 30,000 cu. yd. of concrete were placed during two winters, the greater bulk at temperatures below freezing. Screened and washed sand and gravel were brought in by hopper cars to stock piles or directly into the aggregate house shown by Fig. 46. The house completely enclosed the bins, even to doors at the entrance end. From it, the incline to the mixer house was enclosed, and so was the belt conveyor to the charging floor from the cement house. In brief, every operation of bin storage and concrete proportioning and mixing was housed, and the buildings were steam heated; there was not one unsheltered operation or one without com-

[1] Lundorf-Bicknell Company, Cleveland.

fortable warmth. The bins held 300 carloads, and there was space on the tracks for six loaded cars. On the bin bottoms there were two steam pipes, and also on the posts in the bins three tiers, five pipes high. With doors closed, the bins were kept at 60°. A 9,000-gal. tank with a steam coil in the bottom heated the water to 100°. The concrete left the mixers at 80 to 90° temperature.[1]

A heating shed for thawing and warming materials in cars is shown by Fig. 47. This structure was used on building work near Chicago.[2] The entrance end was closed with

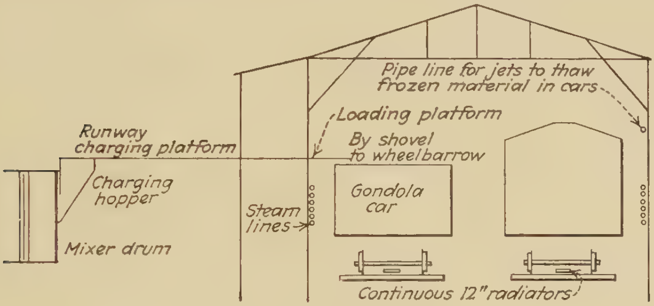


Fig. 47.—Heating house for aggregate in railway cars.

curtains of canvas and when shut tight for the night the inside temperature run up to 100° at −10° outside. The shed held 12 cars.

79. Aggregate Temperatures.—The temperatures to which aggregates are heated, where actual heating and not merely thawing is undertaken, in practice varies from 40° to temperatures exceeding 100°. Sand, gravel, and broken stone have low specific heat and they lose temperature rapidly in handling. It is not common, perhaps, with ordinary practices, that aggregate can be got into the mixer at upward of 50 to 60° heat.

80. Flame Heating in Mixer.—Heating in the mixer ordinarily may be considered as supplementary to preheating the materials, its function being to repair loss of temperature in charging and mixing and to give, perhaps, a few

[1] Morton C. Tuttle Company, Boston.

[2] Thompson-Starrett Company, Chicago.

degrees added temperature. For the ordinary mixing period, the gain in temperature cannot be large. In about a score of runs made by the Pennsylvania highway department using flame injection, the results in Table VII were obtained:

TABLE VII.—TEMPERATURES GAINED BY FLAME INJECTION INTO MIXER

Run number	Concrete, degrees Fahrenheit	Minutes in mixer	Run number	Concrete, degrees Fahrenheit	Minutes in mixer
	First series				
1	55	1¼	2	60	1¼
2	56	1¼	3	59	1¼
3	59	2	4	58	1¼
4	62	3	5	62	2
5	65	4	6	63	2
6	70	5	7	65	3
7	75	7	8	66	3
	Second series		9	72	5
1	59	1¼	10	71	5

In the first series the original temperatures were: air, 45 to 46°; water, 49°; aggregate, 40°; and cement, 45°. In the second series, they were: air, 43°; water, 48°; aggregate, 42°; and cement, 47°.

For ordinary mixing periods, a temperature increase of about 10° was recorded. On building work in New York City in 1926–1927, with water heated and aggregates at outdoor temperatures, a flame heater for the regular mixing period of 55 sec. increased the temperature of the concrete about 10°.[1] A ¾-cu. yd. mixer used on the Spier Falls power plant was fitted with two kerosene torches placed side by side in the charging opening. The mixer rotated at 17 r.p.m. A 20-gal. supply tank fed the torches, which consumed about 3 gal. each per hour. Air pressure on the torches was irregular, varying from 30 to 75 lb., causing trouble by putting out the flames. Wind at times also extinguished the torches. The best pressure was 30 lb., and it was important that it be constant. Lighting by hand was dangerous; a gas-range igniter attached to an acetylene gas tank was kept for lighting. Sand, cement, and water were put into the mixer and turned a few times,

[1] Tucker Construction Company, Inc., New York.

and then stone was added. The torches were then turned on full for 1½ to 2½ min.; this generally gave a mix temperature of 70 to 80°. Each additional half-minute, it was found, raised the temperature about 22°.[1] Torches specially designed for mixer heating are on the market, and have been rather extensively used for small mixers.

At the Toltec dam in New Mexico at an elevation of 8,000 ft. a preflame gasoline torch, with the nozzle just outside the drum, directed the flame against the rising side of the drum and through the falling concrete. The torch was merely a large pressure tank with a flexible feed line and a preheating nozzle with air vents. With aggregates above 20° no flame was used, dependence being placed on the mixing water heated to 200°. With colder aggregates, the torch was kept turned on through the mixing period. The general procedure was as follows:

In starting, the torch was turned on full with the drum full of hot water. When the water reached the boiling point, it was dumped down the chute line and a batch of concrete was put in the mixer. The usual mixing time was used and the temperature of the concrete was taken at the chute hopper. If this temperature was from 90 to 105°, the usual time was used on the next batch. If a hotter temperature was recorded, the torch was cut down, and if colder, the mixing time was increased. The temperature was read at the point of placement, and after the chutes were thoroughly warmed up, the torch and mixing time were regulated to give 85°. The temperature added by the torch was not determined but only during a cold snap in December (0 to −26°) was it necessary to increase the mixing time of 1½ min. From five to ten batches were poured to establish temperature control. The instructions were to keep below 115° at the mixer and above 85° for the first few batches to provide plenty of heat against the cold concrete and forms.[2]

81. Heating Mixing Water.—For the ordinary operation, live steam injection into the water tank is about the sim-

[1] C. Voetsch, engineer.

[2] A. F. Schramm, engineer.

plest and most effective method of heating mixing water. A 1- to 1½-in. pipe turned down into the tank to within a few inches of the bottom and provided with a valve at the hand of the mixer operator is the usual device. For large tanks, (5,000 to 10,000 gal., supplies, as in the case of heavy construction) a steam coil in the tank is preferable to the steam jet. This was the arrangement on the Gulf Island dam,[1] where there was a 9,000-gal. tank, and an average of 350 cu. yd. of concrete every working day was placed during the coldest weather. On power-house foundation construction,[2] a water-tube hot-water service heater rated to heat 4,300 gal. an hour from 50 to 170°, with 80-lb. steam, was installed at the mixing plant. This gave hot water, both for mixing and for washing out chute lines. In general, a modification of one of the three types of heating devices described is practicable on any winter concreting operation. On small bridge work in Michigan, a coil of pipe in a large salamander has been used to heat up to 20 cu. yd. or so a day. On the same type of work where the water could be drawn directly from the stream below, good success has been had with steam ejectors, or siphons, which both pump and heat the water.

Water may be heated to any temperature up to boiling if it is desired. The concrete will not take harm from boiling water. At the Castleton bridge,[3] boiling water was used and the concrete left the mixer at 125°. Ordinarily, the temperatures used range from 100 to 150°. This heat is easily practicable by the methods described. The water has to be hot if the concrete is to be hot. Aggregate generally does not get into the mixer often at exceeding 50°. According to observations,[4] it takes 6° water temperature to raise 1° the temperature of the other concrete ingredients, so if their temperature is 50° and the water is 150°, the resulting concrete will be not over 67°.

[1] Morton C. Tuttle Company, Boston.
[2] Kenn-Well Contracting Company, New York.
[3] New York Central Railroad, W. F. Jordan, engineer.
[4] Turner Construction Company, New York.

CHAPTER XII

HANDLING AND PLACING CONCRETE IN WINTER

Heat put into concrete in mixing has to be conserved in taking it to the forms and putting it into them. This process has been as little perfected as any in winter concreting. It indeed offers great obstacles. The distance moved, the frequent pourings, the operations of spreading, puddling, etc., all expose the concrete to great radiation losses and none of them is easily guarded against by shelter or heating.

82. Loss of Heat in Placing.—The radiation loss naturally varies with the degree of exposure and the time consumed in handling and placing. In ordinary operations it is seldom less than 20°. Generally, it is least in large-volume buckets or other containers handled quickly by motor truck, railway, derrick, or cableway. When, as in mass work, they can be dumped in full loads one after another about as rapidly as they can come along, another advantage is had. The radiation is greatest when chutes, belts, or other continuous conveyors are used. Carriage by barrows or hand carts takes a middle position in heat losses. There are few determined records of heat loss in handling and placing concrete.

83. Carriage in Containers.—On the Wacker Drive in Chicago, with hand-cart distribution, concrete leaving the mixer at 75 to 80° recorded not over 60 to 65° in the forms, the outside temperature being 10 to 20°.[1] On the Lake Humphreys dam in Colorado, concrete leaving the mixer at 80°, and carried by wheelbarrows to short chutes into the forms, reached the forms generally at less than 40°. A notable record of mixing, placing, and hardening temperatures (Table VIII) was kept in constructing a bridge at

[1] Mid Continent Construction Company, Chicago.

Waterloo, Iowa, in 1922. The placing was not far from the mixer and the heat loss was small.[1] On the Gulf Island dam, with carriage in 2½-cu.-yd. cars, thermometer readings showed virtually no loss of heat in 30 min. in the car. The temperature at the mixer was 80°; with pouring and chuting, concrete went into the forms at about 60 to 70°. With approximately a ½-mile haul in 4-cu.-yd. buckets at Isle Maligne dam on the Saguenay River, the heat loss in the containers was inconsiderable.

84. Gravity Chuting.—In reconstructing the Spier Falls power plant in New York in 1924, in chuting concrete from the mixer to the hopper of a tremie, a drop of 10° occurred in 50 ft. of chute. In a specific case, with the mixing water at 85° and mixing 2 min. in a flame-heated mixer, the concrete left the mixer at 89° and reached the tremie hopper at 60°.[2] On the Toltec dam in New Mexico with the chute line ranging from 400 to 600 ft., the heat loss in transit varied from 10 to 15°. In the thin dry air (elevation, 8,000 ft.), variations in wind velocities and direction gave widely different losses.[3] Reporting on the same operation, the contractors state that at a temperature around zero, concrete which left the mixer at 80°, passed through 350 ft. of chute to the tower, was hoisted 100 ft. in an open bucket, and then chuted 100 ft. to the forms, lost about 10° of temperature.[4]

There are many examples of safe chuting up to 600 ft., but the temperature records are few. On work at Winton, Minn., in 1925, concrete was poured when it was as cold as 40° through 600 to 700 ft. of chute. The concrete left the mixer "very hot," both heated aggregates and water and flame heating in the mixer being used.[5] In constructing a dam at Fond du Lac, Wis., in 1926, concrete was chuted 600 ft. at 30°, using heated aggregates and hot water. A

[1] G. F. Scales, contractor.
[2] G. Voetsch, engineer.
[3] A. F. Schramm, engineer.
[4] Anderson Bros., El Paso, Tex.
[5] Siems, Helmers & Schaffner, Minneapolis, Minn.

feature of this work was heating the chutes by running hot water down them before beginning to pour concrete and after pouring stopped. This consistent washing warmed the chutes and kept them clean.[1]

In chuting in winter the precautions to be observed are: (1) Keep the distance of chuting down by arranging the work so as not to require long chute lines; (2) mix the concrete very hot; (3) warm the chutes and keep them clean with hot water; (4) watch the temperatures by means of frequent thermometer readings. The possibilities of housing chutes do not appear to have been developed in practice. They are worth considering at least for the fixed chute lines. A simple canvas housing used to prevent spattering and as a safeguard for the chute linemen is shown by Fig. 48. This should afford material protection from wind and wind has a greater chilling effect than a still cold which gives much lower temperature readings. Another possibility is a small steam line along the chute. This, with a light chute boxing, should keep down the loss of heat to very moderate amounts.

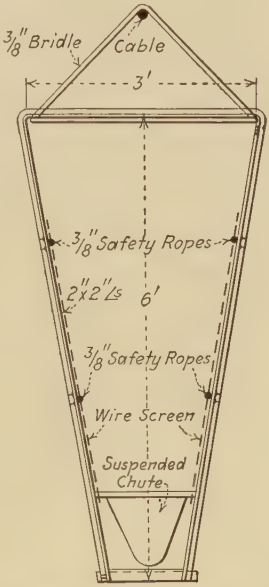


FIG. 48.—Canvas wind shield for gravity chute lines.

85. Reheating in Transit.—Ordinary methods of handling concrete offer little opportunity for applying heat in transit. On the Chelsea dam near Ottowa, Ont., where side-gate hoppers on steel cars permitted them, wood fires were kept burning on the car tops under the hoppers.[2] These, it is believed, cut down the radiation loss through the steel hopper walls. The possibilities of reheating in chuting concrete have been spoken of.

[1] Phoenix Utilities Company.

[2] Fraser-Brace Engineering Company, Montreal.

86. Heat Development after Placing.—The heat generated by concrete in setting is of practical importance to the winter builder. If it be great enough and lasts long enough to exceed radiation losses to below 50° until the danger period of frost is passed, it virtually solves the protection problem. In heavy mass work, heat generation

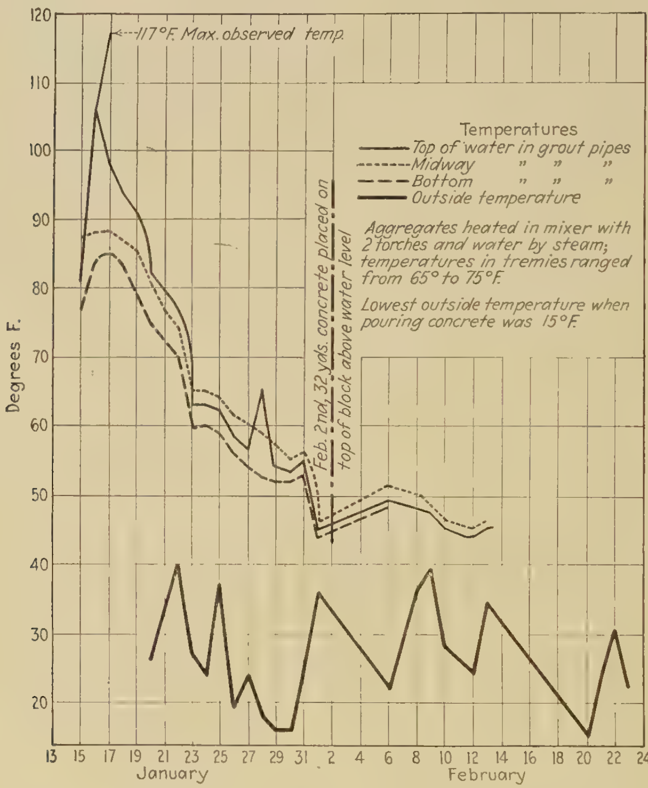


Fig. 49.—Interior temperatures of concrete at Spier Falls Dam.

is enough to keep the concrete safe from frost, except, perhaps, for a thin surface shell. With light, thin sections, there is not sufficient heat development to offset heat loss by radiation. It is for heavy concrete work that data of heat development are most useful. They are not many and the following records include the more important.

At the Spier Falls dam, studies of temperature in the body of concrete placed during January and February gave the

results shown by Fig. 49. The readings were taken in grout pipes 1 to 2½ ft. from the exposed surfaces, where the water was at 32°. The marked rise of temperature due to chemical action after the concrete was deposited is of interest.[1] In building the largest dam of the Lake Kenogamie storage reservoir in Quebec in 1923–1924, some 7,244 cu. yd. of concrete were placed from Dec. 1 to Mar. 15. During January and February the temperature was seldom above zero and, as a rule, varied from 10 to 20° below, with a minimum record of 35°. The concrete went into the forms at about 70°. Records of the concrete temperatures after placing showed a rise during the first 24 hours to 120°, and then a gradual decline to 32° in 3 weeks. Notable evidence of mixing, placing, and hardening temperatures was recorded, as in Table VIII, in 1922 in building an arch bridge at Waterloo, Iowa. Water was heated by steam jet and the mixer by a Hauck heater for a mixing period of 1¼ min. The rise of temperature after placing is to be observed; the figures are an average of ten holes in each pouring.[2]

In constructing the anchorages for the Delaware River bridge, concreting operations were carried on during the winter with few interruptions from cold weather. It was found that by heating the aggregate and mixing water to a temperature of 60 to 75°, the mass would maintain a temperature of 40 to 50° for several days after pouring, although the air temperature was between 15 and 25°. It was usually found that the temperature would rise 4 or 5° the first 24 hours after mixing, due to the chemical action of the setting of the cement.

87. Limiting Placing Temperatures.—Practice records no temperature to 30 to 40° below zero at which concrete cannot be successfully handled and placed. Perhaps the most extreme test comes in outdoor work in exposed dam construction. The winter concreting records of three such operations are given by the graphs of Figs. 50 to 52. On

[1] C. Voetsch, engineer.

[2] G. F. Scales, contractor.

two of these dams the protection after placing was of the simplest form; on the third it was elaborate.

The Saguenay River power development at Isle Maligne, Que., furnishes an excellent example of large handling units and cold-weather quantity placing in building the first lift of the dam. The mixing plant had two 4-cu.-yd.

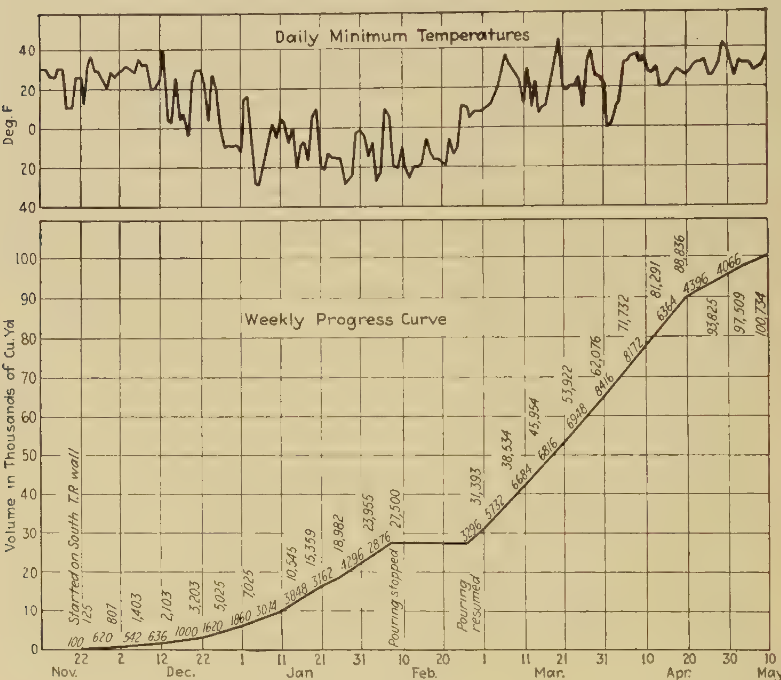


FIG. 50.—Placing and temperature charts at Isle Maligne Dam, Quebec.

mixers which discharged into 4-cu.-yd. buckets hauled four to a flat car and placed by traveling cranes. Figure 50 shows the output and temperature graphs from November to May, 1923–1924. Virtually 100,000 cu. yd. were put in below freezing and much of it below zero with no further precaution than warming the concrete mixture. The large containers with quick handling and quick placing in batch units conserved the heat put into the concrete at the mixer.

At the Lake Humphreys dam, in Colorado, most of the concrete was placed at below 40°, using wheelbarrows and

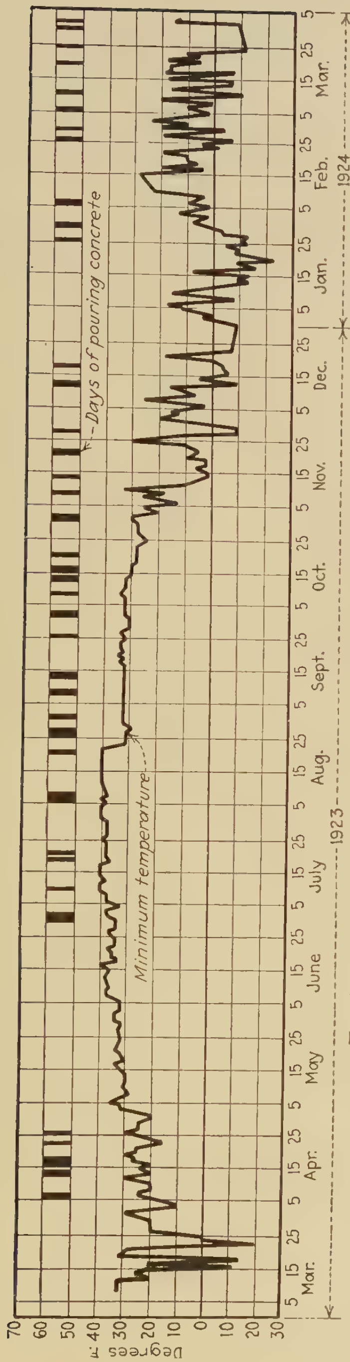


FIG. 51.—Placing and temperature charts at Lake Humphrey's Dam, Colorado.

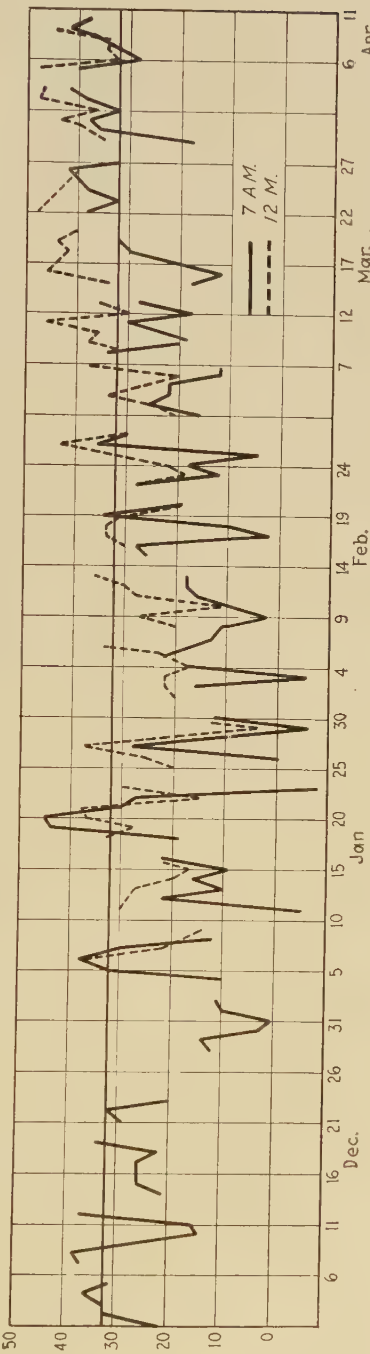


FIG. 52.—Placing and temperature charts at Gulf Island Dam, Maine.

carts to chutes into the forms. The graph of Fig. 51 shows the record. There were no frost troubles, using the materials-heating methods and the protection after placing which are described in Sec. 76. The cost of this protection varied from $1.40 to $2 per cubic yard of concrete protected.

On the Androscoggin River dam operation at Gulf Island, Me., concrete was taken out to the structure in 2½-cu.-yd. cars hauled by gasoline locomotives and then dumped from the cars into chutes to the forms. The chart (Fig. 52) shows the concreting operations during the first winter. The point to be noted is the temperature variation and the fact that placing continued at all temperatures; about 2,300 cu. yd. a week was the average. Totaling everything, including rehandling gravel, snow removal, housing, and heating, the extra cold-weather cost was about 10 per cent of the concrete cost.[1] On the Toltec dam, built at an elevation of 8,000 ft. in New Mexico, concreting started early in October and freezing weather came nightly within a few weeks, the high altitude accentuating the daily variations. The temperatures ranged as follows:[2]

Dates	Daytime maximum	Night minimum
Nov. 1 to 10	50 to 60	22 to 28
Nov. 11 to 15	30 to 45	4 to 10
Nov. 16 to 30	33 to 50	18 to 25
Dec. 1 to 15	25 to 40	15 to 22
Dec. 16 to 23	5 to 15	0 to 26
Dec. 24 to 31	No concreting	−4 to −18
Jan. 1 to 12	No concreting	0 to −18

88. Preparing Foundation.—Concrete should not be placed on frozen ground or on rock covered with ice. When, therefore, foundation pits have been excavated, they should be kept from freezing until concrete is placed or, if frozen, they should be thawed before concreting begins. Indeed, it is often insisted that rock foundations should be given a

[1] Morton C. Tuttle Company, New York.
[2] A. F. Schramm, engineer.

thorough warming before concrete is deposited so that the cold rock may not too quickly chill the bottom layer of concrete. In the same line of precaution it is required that the first layer of concrete against the rock shall be thick and of a specially hot mix. Various ways of warming and thawing foundation beds are practiced.

On the Gulf Island dam, the foundation bed to be concreted on the next day was covered, with a canvas shelter on staging, the day before, and this enclosure kept warm by salamanders and steam jets. These thawed and warmed the rock surface enough to remove any ice and then the concrete at 80 to 90° was put on in a good thick layer. The dam was concreted in sections 39 ft. long and the width of dam at the footing ranged up to 80 to 90 ft. A similar method was developed on the Lake Kenogamie dams. The section to be concreted was covered over with a large tarpaulin, blocked up, and heated underneath with stoves for at least 12 hours. Heating by steam jet was found less effective than stoves as the escaping vapor readily formed ice. Hot water was found to be the most effective means of removing ice and snow. When concreting was begun it was rushed, 60 to 70 cu. yd. an hour, and the concrete was put in at 70°. Virtually the same procedure was followed in preparing placed concrete and forms to take new concrete. Despite the objections discovered at Kenogamie to steam jets, they have general approval of contractors for thawing frosted surfaces—foundation beds, placed concrete, and exposed forms. Another device useful in defrosting foundation bed rock is the Hauck heater. This or any other flame heater lessens the water left to refreeze after thawing while steam or hot water adds to this water. At best, the defrosting of a rock foundation in subzero weather is not an easy or comfortable labor.

Considerable dependence can be placed and indeed some contractors do place main dependence on the capacity of the concrete deposited warm to defrost the surfaces against which fresh concrete may be placed. Dam construction on Dead River in northe n Michigan in 1917–1918 is an

observed example. At temperatures below zero more often than above freezing, in December, January, and February, concrete heated by steam coils in bins and water tank to 40 to 65°, average 50°, was placed in sections which insured about a 5-ft. lift per day shift. At first at night, canvas, blocked up, was spread over the concrete, and steam jets turned on underneath. Except near the jets, the concrete froze. Enclosure and heating were then abandoned, and the concrete was left exposed to freeze. This it did—in subzero weather—to depths of 2 to 3 in. Attempts to remove the frozen top by picking proved laborious and delayed concreting. The frozen layer was then hosed with hot water just enough to thaw the top skin of frozen laitance; hot water proved more effective than steam. The warm fresh concrete was then placed, and observations showed that its heat completely thawed the top frozen layer.

In concreting the Toltec dam in New Mexico, the pours were made in sections 12 to 16 ft. long, the width of the dam and 4½ ft. thick. With the sudden drop in temperature in December (Sec. 87) salamanders under the tarpaulin covers proved inadequate to prevent freezing and frost penetrated the top a few inches. With daytime temperatures from 5 to −18° and night temperatures from −18 to −26°, readings in freshly poured concrete under tarpaulins showed 28° at 2 in. and 34° at 4 in. in the concrete. The contractor ceased work during the extreme cold and on resumption it was found that gradual thawing and resetting made little chipping necessary.[1]

89. Placing under Water.—Special methods of placing concrete in water close to freezing have not been often recorded. At the Mystic Lake power development in Montana, where the bottom of the control shaft and some 80 ft. of adjacent tunnel bottom had to be concreted in water at 32 to 33°, the tunnel was bulkheaded to enclose the section to be concreted, and the water in this enclosure was heated by steam jets to about 45°. The concrete

[1] A. F. Schramm, engineer.

went in at about 50°. In the work at Spier Falls dam, placing concrete in heavy wallforms under water, the concrete entered the tremie hoppers at 60 to 70°. It not only set up perfectly but also developed the temperature given in Sec. 86.

90. Detecting Frozen Concrete.—Concrete should not be permitted to freeze in winter construction. Like most things, however, which should not be allowed, freezing occurs. The following methods of detecting frost and thawing concrete are based on a discussion by A. M. Bouillon who has had much experience in winter construction in Canada.

The easiest and most certain method to determine frost is to apply warm water or a mild flow of steam against the suspected spot. Cut small inspection openings in the forms, say 3 to 4 in. square. These should be so spaced and located as to give positive information to cover all of the concrete faces. The warm-water test, or mild steam-pressure test, should then be applied over the exposed concrete. If frozen, the concrete will be thawed by this application, become soft, and crumble easily.

91. Thawing Frozen Concrete.—The first step in thawing should be to tighten and strengthen all forms, taking into careful account in this operation the height and extent of the frozen concrete, which, when thawed out, will bear pressure against the forms, and also any tributary loading due to construction conditions. Coincident with this, there should be provided proper housing to insure gradual thawing and subsequent complete hydration of the concrete. Having taken these protective measures, the next step will be either to install ½- or ¾-in. pipes along the top of the forms perforated with tiny holes every foot or two, which will provide a flow of water between the face of the concrete and the forms, or arrange for frequent sprinkling with either hose or buckets.

The thawing operation requires care and good judgment. As far as is practicable, it should begin at the extreme bottom of the frozen section, which, if very high, or a

building of several stories, should be extended upward very gradually not more than one story at a time. The water to aid in the thawing will insure curing and also prevent cracks or crazing. The actual time required for thawing the concrete will vary according to the extent of the frozen area and its penetration, but usually it takes 24 to 48 hours to get the frost entirely out of a wall 10 to 15 in. thick and it may take 2 weeks to 1 month to thaw out a frozen pier 8 to 10 ft. thick. As warmth reaches the concrete it gradually resumes the setting and hardening process that was interrupted by the frost. This warmth must first penetrate through the forms and is greatly assisted by the flow of water previously recommended. Warm water in such instances is, of course, more active than cold water, but cold water is much better than no water. The forms should be kept on until it is perfectly assured that the frozen concrete has been fully restored, cured, and hardened.

TABLE VIII.—TEMPERATURES OF CONCRETE, PLACED IN WINTER IN THE SANS SOUCI BRIDGE, WATERLOO, IOWA

Date of concreting	Outside air	Sand	Rock	Water	Before placing	After placing	After 24 hours	After 48 hours	After 72 hours	After 96 hours	Remarks
Dec. 8, 1921	34	34	34	100	75	70	90	93	90	85	Temperature taken at 8
	35	35	35	113	65	60	..	..	..	..	A.M., 12 M., and 3 P.M.
	36	36	36	75	70	65					
Dec. 27, 1921	2	34	34	170	64	58	65	71	77	67	Temperature taken at 8
	12	34	34	160	62	58	..	..	..	..	and 10 A.M and 3 P.M.
	26	34	34	150	64	58	..	..	..	..	Concrete mixed 1½ min.
Dec. 28, 1921	24	34	34	185	64	63	34	60	58	..	Temperature taken at 8
	28	34	34	180	72	65	..	..	..	..	9, and 10:30 A.M. Con-
	30	34	34	172	63	64	..	..	..	..	crete mixed 2 min.
Jan. 10, 1922	16	30	30	145	61	60	64	65	61	59	Temperature taken at 9
	33	34	34	160	64	60	..	..	..	..	A.M. and 4 P.M.
Jan. 26, 1922	30	30	30	160	63	62	73	79	79	81	Temperature taken at 9
	32	34	34	156	66	62	..	..	..	..	A.M. and 3 P.M.

Note: The lowest temperature during the actual depositing of the concrete was 2° above zero, and the temperature on the following day was 10° below zero.

CHAPTER XIII

PROTECTING CONCRETE IN HEAVY SECTIONS

Insulation, enclosure, or heating are required to hold placed concrete at active hardening temperatures somewhere above 50°. All the insulation needed in heavy sections may be provided by the regular forms or these may have to be thickly blanketed. So, also, the necessary enclosure may range from a mere cover of canvas to a complete and tight housing; the heating system may vary from a firepot to steam coils of elaborate arrangement. In discussing these housing and heating methods, a classification into heavy structures and into building construction is adopted. This is for the reason that for heavy structures special and individual designs and arrangements are required for each structure, while in building, the methods approximate standards of general application.

92. Heavy Concrete Structures.—Simple structures and arrangements suffice, in general, for housing mass concrete in bridge piers, bridge arches, dams, walls, and foundations. Dependence, rather, is put on heated concrete and the heat generated in setting to prevent frosting. Their mass in proportion to their surface exposed prevents frost action except at the very surface. Protection, then, is largely directed to keeping the surface unfrozen. Often the insulation of the forms is enough for this, and where more is required the necessity seldom exceeds canvas curtains and covers warmed underneath by firepots or steam jets. Where thin sections are included with the mass work, they must naturally be better guarded in the manner of building construction.

93. Form Insulation.—The insulating value of heavy wood forms is considerable. Steel forms give very little

protection from frost. On the Dead River dam, Wisconsin, in subzero weather, it was observed that with steel forms frost would penetrate 2 or 3 in., when with 2-in. plank there was no freezing. On the Toltec dam in New Mexico at temperatures which would freeze several inches deep the top of the concrete under tarpaulin covers, the sides, protected by 4-in. plank forms lined with 18-in. gage sheet iron, did not freeze. If a curtain is hung over the outside of the wood form, its insulating value is increased by the dead air space which retards radiation. Care must be taken, however, to see that the covering does not have openings which make of it a flue for cold-air currents up the outside of the forms.

More effective form insulation is secured by packing the back of wood forms with marsh hay, straw, or, better, a strawy manure. On warehouse construction[1] in Montreal, 1926–1927, wood panels for wall forms were packed between wales with manure held in place by roofers nailed onto the wales. A five-span concrete arch bridge, two 70 ft., two 72 ft., and one 74 ft., built in 1922 at Waterloo, Iowa, was protected by insulated forms for spandrel walls and by blanketing for the overarch concrete. The spandrel wall forms were boards on 2 × 6 in. studs; between studs was packed a dry strawy manure retained by just enough across-stud battens to hold it. A similar manure insulation blanketed the top of the arch ring. The concrete temperatures on this work are given in Table VIII. Where staining or blemishing the concrete surface have to be avoided, care must be taken in insulating by direct application of straw or manure, also care where they may be displaced by wind.

In constructing the heavy deck slab for the Wacker drive in Chicago, where both housing and insulation were employed, the engineer reports that the heat applied to the materials in the making of concrete was rapidly dissipated in handling.

[1] Parklap, Inc., New York.

Concrete leaving the mixer with a temperature of 80 to 85° F. would show not over 65 to 70° F. by the time it was placed in the forms on a cold winter day (air temperature 10 to 20° F.) and would fall as low as 50° F. by the time it was firm enough to cover with hay to prevent further heat losses. Tarpaulin enclosures, made and maintained with great care, showed very low efficiency in keeping in the heat of the salamanders. Inasmuch as concrete, in setting, generates ample chemical heat for its own proper curing, it would seem that some practical method might be found to insulate the freshly placed concrete effectively against heat loss and that this might prove far more economical than the salamanders and tarpaulins enclosures now generally used. The salamanders have a tendency also to reduce the moisture below that required for favorable curing conditions. On a portion of the deck, under moderate outside temperatures (from 25 to 35°) it was found that covering the slab with hay, including the ceiling as well as the top, gave curing temperatures of from 65 to 75° which were obtained at very little expense and were maintained without extra cost far beyond the specified 7-day curing period.

94. Protecting Bridge Piers.—The massive compact structure of bridge piers and abutments makes enclosure and heating comparatively simple. Generally, canvas curtains over the outside forms and canvas covers over the top, both heated underneath, are sufficient. A typical example is the pier protection employed on the Castleton bridge near Albany, N. Y. The pier was concreted between Jan. 15 and Mar. 15, and the weather was very cold, the thermometer on several occasions going to −10°. The sand and broken stone were stored in piles and kept warm by steam pipes laid in the bottom. The mixing water was heated to near the boiling point and the concrete, as it left the mixer, was at about 125°. To keep the concrete warm in the forms, outside steam pipes were installed and tarpaulins were hung outside the pipes. This protection was maintained for 10 days. Each night tarpaulins were placed over the open tops of the forms and live steam allowed to escape into the space enclosed.[1]

[1] New York Central Railroad, W. F. Jordan, engineer.

In building the Delaware River suspension bridge at Philadelphia, the precautions with concrete on the anchorage foundations during the winter of 1922-1923 consisted of heating the aggregate and water before mixing and of heating the caissons while the concrete was setting. The latter protection was afforded by the use of tarpaulins placed over the top of the green concrete and extended down the sides of the caissons to the bottom of the forms, with heating units placed inside the covers (Fig. 53). In Camden, salamanders were used to provide heat for both

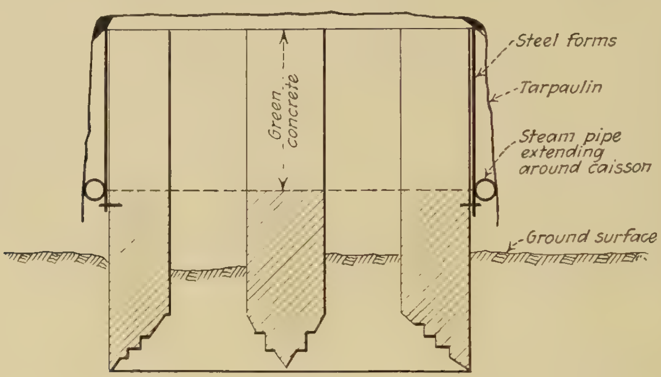


Fig. 53.—Heating and housing for anchorages of Delaware River Bridge.

rectangular and circular caissons. In Philadelphia, salamanders were used for the circular caissons, but steam pipes were employed for the rectangular caissons. A pipe in which holes had been punched was placed around the caisson at the bottom of the forms of the lift to be heated, each lift being 10 ft. high. The tarpaulins were extended down over this pipe. Steam passing out of the holes produced a warm, moist atmosphere, well suited for the setting. Temperature observations were made in oil-filled pipes set in the concrete of the outside walls of the caissons at distances of 6 in., 18 in., and 3 ft. from the outside face. They showed temperatures above 40° with the outside air from 15 to 30°. The steam was supplied from the boilers in the contractor's plant, through asbestos-

covered pipe laid on the construction bridge over Delaware Avenue.[1]

A scheme of heating by steam similar to that employed on the Delaware River bridge anchorages was used in the construction of the Clark's Ferry bridge at Harrisburg, of which Frank M. Masters was engineer. The water and aggregate were heated before mixing, and then a steam pipe beneath tarpaulin covering was used to protect the green concrete. Steam was used for 3 days after the concrete had been poured. Temperatures in the concrete ranged from 60 to 82° when the air was from 20 to 32°. An admixture of cal was used on that bridge and the temperature observations indicated that the effect of cal was more pronounced when the mix was heated. The observations also showed that the temperature of the concrete rose during setting only when the mixing temperature was above 55°. The Clark's Ferry bridge was built in 1924.

As an example of elaborate protection, the diagram of Fig. 54 of bridge-pier housing developed from experience in the winter construction of many such structures on the Grand Trunk Pacific Railway in Canada in 1909–1914 is presented. In general, the work below ground level or ice level can be heated by stoves. On the work mentioned, stoves were provided both outside and inside the forms, those inside being supported on brackets and raised as the surface of the concrete was brought up. For the portions above ice level, the best protection is afforded by a housing built around the forms so as to leave a 2½-ft. annular space in which steam radiators are installed. To protect the top surface, emergency heaters were set on inside brackets around the forms; these were seldom found necessary. Thermometers kept the foreman aware of the temperature. The outside housing consisted of 2 × 6 in. studding spaced 2½ ft., covered with 1-in. boards, and these with two layers of building paper battened on. This protection, with the other devices indicated by the drawing, was found ample at temperatures going frequently to −40°. A 10-

[1] Charles Carswell, engineering staff.

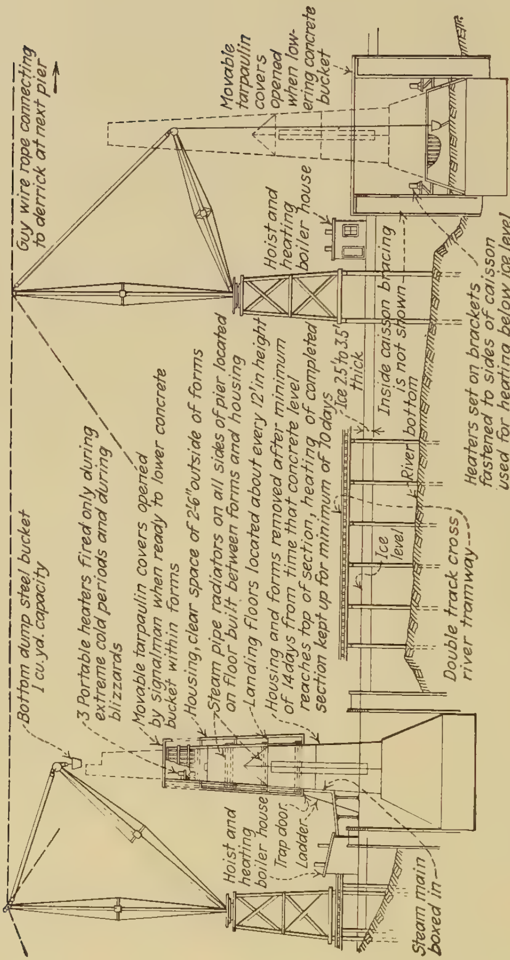


Fig. 54.—Heating and housing for bridge piers, Grand Trunk Pacific Ry.

to 12-hp. boiler at each pier gave ample steam with the exhaust from the hoists. The cost of protection such as indicated will average from 60 to 70 cts. a cubic yard. On other piers under less severe frost conditions, a housing of canvas on frames was employed.[1]

In building piers for a bridge across the Saguenay River in Quebec (October to December, 1925), the temperature ranged from +36 to −16°. A mix of 1:2½:5 was

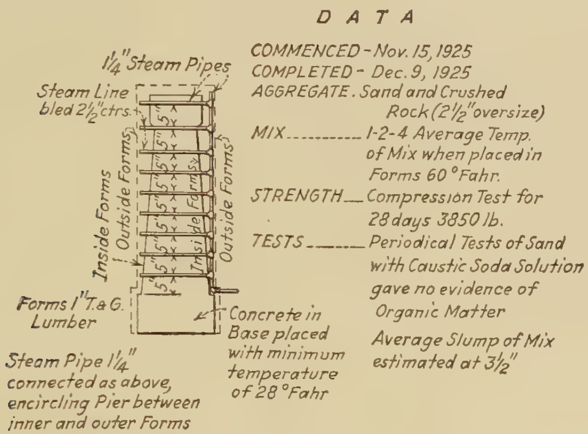


Fig. 55.—Heating and housing for Saguenay River Bridge, Quebec.

used on both abutment and north pier; on the south pier, which was to withstand cantilever action, a 1:2:4 mix was employed. Aggregate was composed of sand and crushed rock, the latter being supplied from a small electrically driven crushing plant erected on the job. Both aggregate and water were heated with jets of live steam, and the mix was in place at all times well above freezing. Double forms were used of 1-in. lumber, with an air space between inner and outer forms. Coils of 1-in. pipe were placed between the forms every 5 ft. of elevation, and sufficient boiler capacity was installed to ensure ample live steam's being liberated to maintain a temperature between the forms of 45° F. Temperatures were checked night and day.

[1] A. M. Bouillon, engineer.

Constant inspection of mixing operations, both of time and of water-cement ratio, maintained a consistent mix, the average slump of which was 3½ in.

The accompanying sketch (Fig. 55) shows the method employed in the building of the forms and the placing of the steam pipes. Steam heat was continued for 10 days after the piers were completed, and the forms were allowed to remain until March. The outstanding feature of the temperature records taken between the forms after steam heat was discontinued was that, in spite of extreme low temperatures prevailing outside, the temperature between the forms remained above freezing point for 9 days.[1]

95. Arthur Kill Bridges.—In building 150 piers (Fig. 56) for the two road bridges across the Arthur Kill near New York, a winter concreting plan of such unusual nature was employed that it is described separately, from a statement by W. J. Boucher, construction engineer.

There were three contractors for the work. The aggregates for all contracts were measured from batcher bins into batch motor truck which delivered the materials directly to the skip or pan of the mixers, which were caterpillar mounted and moved from pier to pier as required. The problem then was to heat the aggregate at a hopper, distant a few hundred feet to over a mile, to such heat that, on delivering into the mixers, the mixed concrete would come out at a temperature of from 50 to 100°. At three of the four hoppers, the sand and stone were heated by steam. Pipes 1½ in. were placed around the four sides of the hoppers; live steam escaped through numerous perforations. At another batcher plant, a 6-in. pipe was placed in the steel hopper; the loose material surrounded this pipe inside of which was the flame of one or two powerful oil-fed blow-torches.

After the heated materials were in the trucks, the entire top was covered with a tarpaulin tied down. The trip from hopper to mixer occupied from 5 to 10 min., according to location, and the last batch in the truck was dumped in 15,

[1] D. C. Tennant, engineer.

sometimes 20, min. after leaving the hopper. Mixing water was heated either in a boiler alongside of the mixer or in a 6-in. pipe under which a wood fire burned; the pipe was large enough to provide a reservoir sufficient for several batches.

Fig. 56.—Typical pier for Arthur Kill Bridges.

Temperatures of concrete were taken by inspectors at frequent intervals, after it had been deposited in the forms. Due to the large area and mass, the concrete retained its

heat for several hours and until initial set had occurred; the form lumber was 2-in. tongue and grooved, dressed, and, of course, served to keep the heat in. At the conclusion of a day's pour, one contractor placed a layer of approximately 2 ft. of salt hay over the new concrete and then covered the top and forms with a tarpaulin well tied down; this more particularly related to the piers or columns after they were some distance above the ground.

Another contractor, working on bases in the cold weather, after finishing the pour, placed planks on top of the mass and set one or two salamanders fed by oil blowtorches and covered the entire base with a tarpaulin tent. The night-watchman kept the air pressure up on the torches during the dark hours.

96. Protecting Bridge Arches and Slabs.—In the bridge at Waterloo, Iowa, previously referred to, the underarch was protected as follows: Under the spans the arch openings from ground to arch ring were closed with tar paper on the outside, falsework posts on each side, and the enclosure was heated by salamanders. Some notable observations of concrete temperatures were obtained on this work as detailed in Table VIII. A similarly neat protection was employed in 1926 at Galt, Ont., on a slab bridge of two 15-ft. spans 47 ft. wide; the clearance abovestream was about 4 ft. Two small mixers were used, one at each end, each with an adjacent gravel stockpile and water barrel, both heated by steam jets from open-end pipes; concrete left the mixers at 80°. Abutments and center pier, all plain walls, were protected by a steam pipe along the top and on each side outside the forms and all covered for 3 days with canvas. Forms were struck in 10 days. The slabs were laid in 2 day's runs, one span each day. Above each span slab two square coils of steam pipe were set on supports with the free ends turned over the edges and underneath the span the sides of which from slab to water level were enclosed with roofing felt nailed onto the falsework. The pipes were covered with manure and canvas and kept

hot with steam for 2 weeks. The concreting temperatures were 28 to 32°.[1]

97. Dam Protection.—Dam construction has called generally for rather simple methods of protection, dependence being put on the hot mix and the chemical heat generated in the heavy concrete sections to prevent frosting. On several of the largest winter dam operations of recent years, the only protection has been (*a*) canvas on light framework or staging to roof over tops of forms being concreted; (*b*) canvas curtains dropped down over the forms outside; and (*c*) heating the canvas enclosures by steam jets or salamanders. Arrangement of enclosure, the space enclosed, and the location and number of heating units are, in each case, a separate problem and require careful study and then careful checking by thermometer readings.

In building the Lake Humphreys dam in Colorado, a rather thin arch structure, the enclosure and heating arrangement indicated by Fig. 57 was employed. Briefly, the cold-weather work plan was: (1) sections concreted 45 ft. long and 12 ft. high; (2) forms for section completely covered with heavy canvas; (3) eight oil heaters placed under canvas at base, three on each side, and one at each end; (4) eight firepots spaced like oil heaters hung 8 ft. below base of canvas and having wood fires; (5) open fires in bottom of canyon above and below dam, heat being carried up the faces and over the top by the wind; (6) flooding the top of the concrete with warm water and letting it drip down the outside; this flooding was carried on for 48 to 72 hours.[2]

Working in the very cold weather of a Quebec winter, the contractors of several storage dams on the Chicoutimi and Ausable rivers report as follows: During January and February the temperature was seldom above zero Fahrenheit, and as a rule varied from 10 to 20° below that point with a minimum recorded temperature of −35°. It was therefore necessary to adhere to the following methods in carrying out concrete operations:

[1] Galt, Ont., Board of Works.

[2] Carl A. Gould, engineer.

· 1. The forms and rock foundation, or previously poured concrete, which were to be in contact with the new concrete had to be cleaned of all ice and warmed. This was done by covering over the section with large tarpaulins and keeping several stoves burning under the cover for at least 12 hours previous to starting the concreting. Heating the section

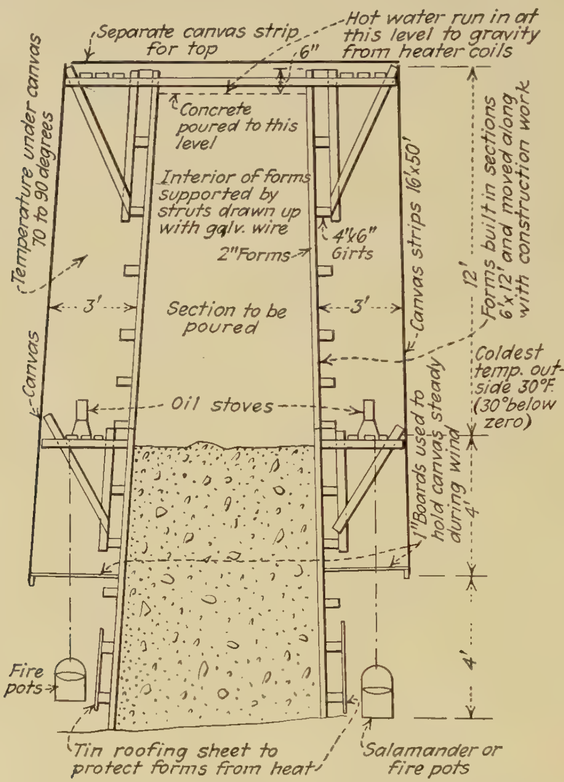


FIG. 57.—Heating and housing for Lake Humphrey's Dam.

by steam was not found to be so suitable as by stoves, as the escaping vapor readily formed ice. Hot water was found to be the most efficient means for the removal of ice and snow.

2. The temperature of the freshly mixed concrete was maintained around 70° F., and it was protected against exposure to cold as much as possible. This temperature was obtained by heating the sand and water by steam jets. The stone and cement were not generally heated but the

exhaust from the mixer engine was so arranged that it could be discharged into the drum of the mixer when desired.

3. Once concreting was commenced it was proceeded with as rapidly as possible. (With the two mixing plants in operation from 40 to 50 cu. yd. of concrete per hour were poured.) No plums were placed owing to the expense which would have been entailed in heating them.

4. As soon as concreting was completed the green concrete was covered over with tarpaulins under which steam jets were inserted.

No damage was experienced from frost, although at this dam 7,244 cu. yd. of concrete were poured between Dec. 1 and Mar. 15. Records were kept of the temperature in the concrete after pouring by readings taken on the thermometers which were lowered down pipes built into the work during construction. It was found that the temperature of the concrete rose during the first 24 hours to between 110 and 120° F., after which it usually dropped gradually, taking 2 or 3 weeks to reach 32°. Commenting on this work the contractor says:

Much has been said and written lately regarding the economy of carrying on construction work during the winter months in Canada. From the point of view of the owner or user, as in the case in question, it will often be advisable to pay the extra cost of winter work in order to have the use of the structure several months sooner. The engineer also need have no fears for the quality of the work, for with proper precautions taken, the results obtained in the winter generally compare quite favorably with work done during the warmer months. The contractor's viewpoint, however, may be very different unless he is well protected with a special price for winter work, for to perform good work of the nature here described in a temperature which persistently remains below zero for weeks at a time is an expensive undertaking.

In zero weather it was found that the carpenters' output was less than 50 per cent of their normal, that from 1 to 2 hours were often lost in the mornings in shoveling snow, thawing out machines, uncovering forms, melting ice, etc., and that the

consumption of coal was doubled if not trebled. Mechanical breakdowns are much more frequent in severe weather, with resulting loss of time, while the difficulty of washing off rock foundations preparatory to concreting in sub-zero weather can best be realized after it has been experienced. It was found that the cost of winter work was from one-third to one-half higher than similar work in mild weather.[1]

[1] Nova Scotia Construction Company, Ltd., Sydney, N. S.

CHAPTER XIV

PROGRESSIVE CANVAS HOUSING FOR BUILDING CONSTRUCTION

Proficiency in winter construction has reached its highest development in building work. Building contractors of the higher class today make no distinction between seasons in undertaking and prosecuting construction. Their methods do not extend beyond or differ from those employed in other engineering construction in winter but they have them more completely standardized and more highly perfected, particularly in the ways and means of sheltering and heating both the working operations and the finished work. It is this phase alone of winter concrete building that will be considered here. Alumina concretes and high early-strength concrete mixtures have not been used to any considerable extent as a means of combating frost in building work. The use, also, of admixtures like calcium chloride has been only occasional. Instead, dependence is put on the use of heated concrete and of enclosing the work and keeping it warm for the longer period necessary to safeguard conventional mixtures. The nature action and possible utility of these special mixers for winter construction are considered in Chap. X. Methods of heating concrete and insulating coverings and form insulation are considered in Chaps. XI and XIII.

98. General Requirements.—Concrete, as used in buildings in thin floor and wall slabs and in slender column and girder forms, offers little resistance to frost action. When freezing occurs there is positive structural hazard. These facts have so often been demonstrated by disaster that argument need not be extended. All the structure of a concrete building must be protected and kept warm till the concrete has gained strength. There may be no safe deviation from this rule.

99. Progressive Canvas Housing.—Protection by enclosing progressively portions of the building with canvas curtains and heating the enclosure is the most common practice. In general, the procedure is: As the structure goes up story by story, each story or portion of a story is enclosed (Fig. 58) progressively with the concreting operations, the housing, generally canvas curtains, being taken

Fig. 58.—Typical wall curtain and floor covering enclosure.

down from the cured work and reerected ahead for new work. The heating arrangements are shifted with the housing. Methods are best explained by an account of typical good practice and then noting differences in practice and special details.

For any story, with the forms erected for columns and floor, hang canvas curtains from the exterior beams of the floor to be concreted and lash their bottoms in under the exterior beams of the floor below. In hanging the curtains brace them out from the building so that there will be space between them and the exterior column and girder forms for

the circulation of warm air. Also carry their bottoms well below the exterior column footings and bind them in tight (Fig. 59). Here at the column bottoms is the frost danger point. With the exterior curtains hung, carry across the building a partition—curtains shutting in the section concreted. This completes, normally, the enclosure. In it, for heating, locate a salamander at each exterior

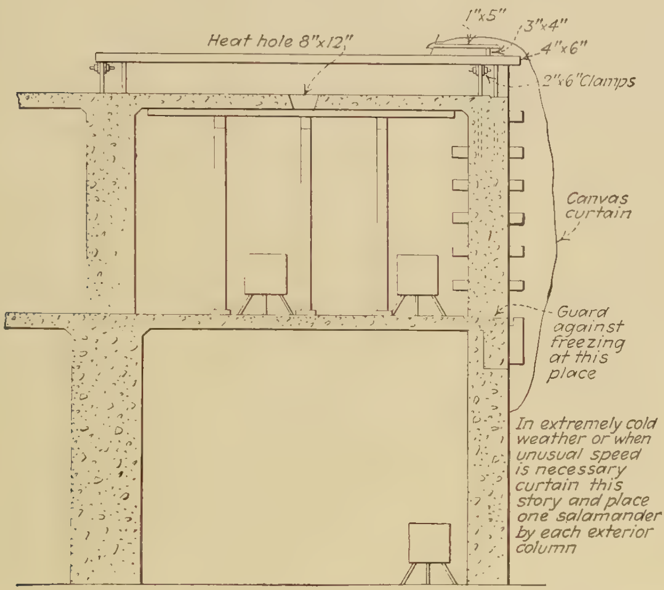


Fig. 59.—Detail of wall curtain and floor covering arrangement.

column form and one at the middle of each bay; in extreme cold weather place a salamander on each side of each exterior column. It may be also desirable in this frost danger zone to supplement heating and curtaining with hay packing or other insulation. The requirement is that in all parts of the inclosure the temperature must be kept at 60 to 80°.

In climates of continued extreme cold or when the progress is exceptionally rapid, it is necessary to curtain the story below that being concreted, or, rather, to leave the original curtaining in place, and heat it with a salamander at

each exterior column for at least 2 days. This story-below housing is also necessary if concrete exterior walls are being carried up monolithically with the columns. Figure 60 shows a recommended arrangement; generally the heat holes are needed only in the case of blank walls.

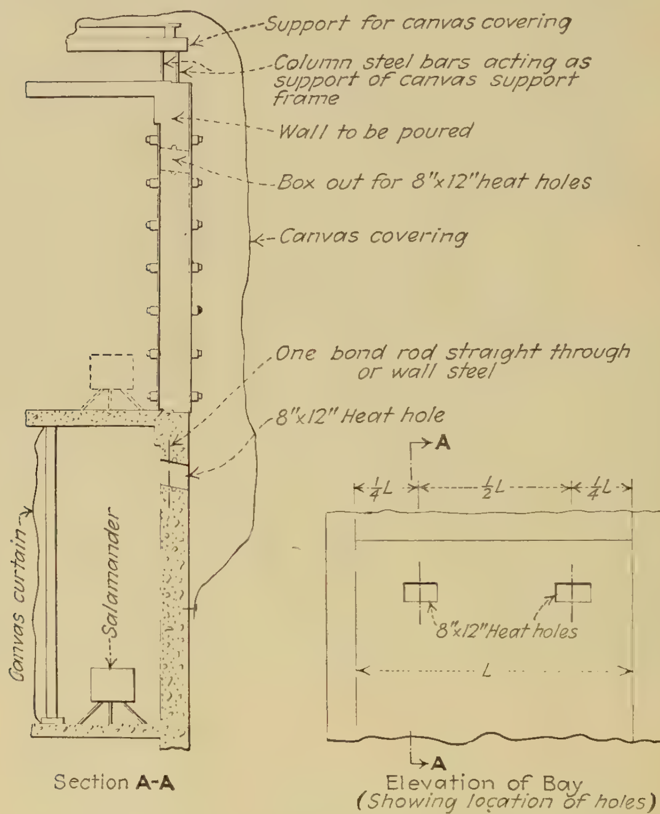


Fig. 60.—Curtain protection for integral wall construction.

In beginning concreting, the side curtains should be in place and fires going in the salamanders. If the cold is extreme, enclosure and heating had better precede concreting by several hours. The next step is to remove with steam jets any snow in the forms or any ice on the steel. These operations should be performed after the work is enclosed and heated or else the steam vapor will again form

ice. Practice in concreting columns approves both pouring a day ahead of pouring the floor and pouring columns and floor slab monolithically the same day. In the first instance, enclosure and heating must have been installed and protection provided for the column tops; in the second very great care must be exercised to make sure that there is not shrinkage cracking between the column top and the floor slab.

The enclosure described leaves the slab concreting unprotected. This requires separate covering as the work progresses. As soon as a bay of slab is poured it should be covered (Fig. 58) by a tenting of canvas. A common method is to clamp 2 × 6 in. pieces to the column steel and on them set 4 × 6 in. timbers spanning between columns. On these girder timbers lay 3 × 4 in. joists and over them spread canvas with care to give plenty of overlap and to make it everywhere fast and tight. The clear height of this covering should be 6 in. and not over 18 in. Instead of pieces clamped to the column steel, posts set on the column concrete or on the wood frames of the heat boxes may be used to carry the framework. To get heat under the covering, holes are left in the slab forms and slabs to the inclosed heated story below. An 8 × 12 in. hole for each bay under 20 ft. square or elsewhere a hole for every 300 sq. ft. of slab is required. A temperature of 50 to 70° under the top covering is required. Designs for the slab protection described are given in Fig. 61.

Proper protection as described involves verification of temperature constantly as the work goes on. A blank for reporting thermometer records is shown by Fig. 62. It calls, as will be noted, for two thermometers at two different places and for five readings each 24 hours. The time and manner of removing protection varies with the type of construction. For slab and girder floors, the top covering may be removed in 48 hours, at the time covering the heat holes with boards. In 48 hours, too, the exterior columns may be stripped but it should be done quickly so as to require loosening of the side curtains for as little time

as possible. The side curtains can be removed in 96 hours and the girder forms stripped and 24 hours later all the forms. In flat-slab construction the top cover should remain 72 hours when the exterior columns may be stripped.

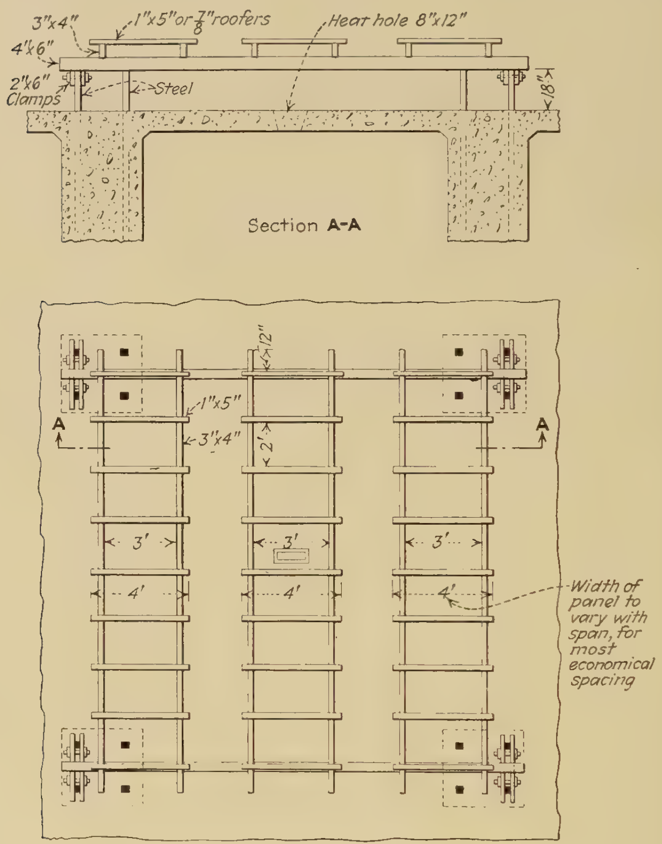


FIG. 61.—Detail of supports for floor covering.

The side curtains may be taken down in 120 hours when the floor forms can be taken down.

Canvas for curtains, it has been found by leading builders, is most convenient when made up in standard size units. A sketch of such a unit[1] is shown by Fig. 63. The specifications are:

[1] Turner Construction Company, New York.

TEMPERATURE RECORD

Important - Give proper date under each hour column	7 A.M.	1 P.M.	5 P.M.	10 P.M.	3 A.M.
Outside Temperature					
At bottom of Exterior Columns Thermometer No 1 at Col. No.					
At bottom of Exterior Columns Thermometer No. 2 at Col. No.					
At under side of slab					
Under canvas over slab Thermometer No 3 at Col. No.					
Under Canvas over slab Thermometer No 4 at Col. No					
Temperature of concrete as it is placed in forms					

FIG. 62.—Form for temperature records.

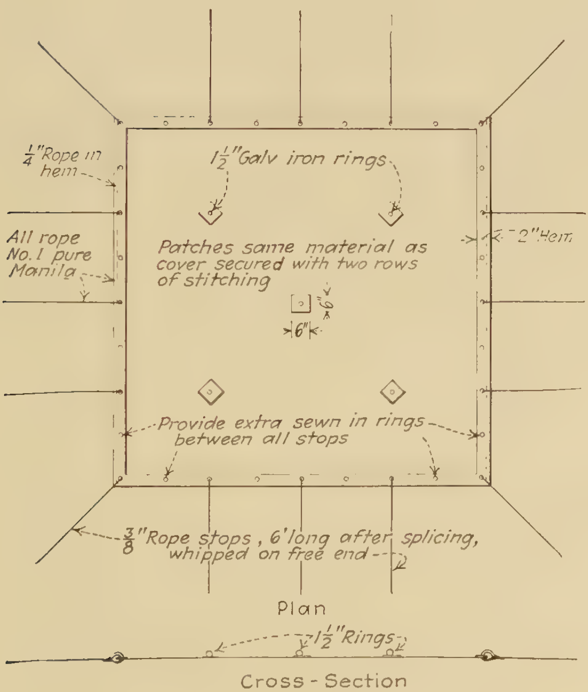


FIG. 63.—Curtain unit for wall protection.

Covers to be made of 12-oz. U. S. standard army duck $28\frac{1}{2}$ in. wide. Covers to be 20×20 ft. finished size and must measure full size without stretching upon delivery. All sewing to be two-row lock stitched with six stitches or five cord Weetamoe soft-finish thread or heavier per inch. Seams to be at least 1-in. wide. A 2-in. hem is to be sewn over a $\frac{1}{4}$-in. pure manila rope all around the four sides of the cover. Each cover to be provided with a $\frac{3}{8}$-in. rope stop 6 ft. long after splicing at each corner and to have three additional stops on each side between corner stops. All stops to be shipped on the free end and to be spliced through a sewn-in ring. Place extra sewn-in rings in the hem midway between the above stops. All covers to be made with five 6-in. square patches sewed on to one side of the cover. One of these patches will be placed in the middle of the cover and the other four patches will be placed, one each midway between the center patch and each corner of the cover. To each of these patches is to be securely sewn a $1\frac{1}{2}$-in. galvanized-iron ring.

100. Variations in Practice.—The preceding methods of progressive protection are based on the practice of the Turner Construction Company, New York. The practice of other good builders differs only in detail. In covering the floor slab some prefer a higher shelter, so that finishers can work under it. On building work in St. Louis,[1] a frame was set up over each bay as it was poured. A 2×4 in. post was set up over each column so as to give 5 ft. clear headroom. This enclosure was heated from the floor below by holes left in the slab about every fourth panel. A salamander was set at the center of each panel and two at each exterior column. The inside temperature was kept at 70° with outside temperatures as low as 10°. The materials and labor for heating and protecting the concrete cost about $1.50 a cubic yard. Another example of high covering is a five-story garage in Buffalo, N. Y.[2]

The building was 105×150 ft. with columns spaced about 25 ft. both ways. Forms were erected for a complete story. On these was set up the housing for the slab. This consisted of a light frame of wood 5 ft. high at the outside

[1] Fruin-Colnon Contracting Company.
[2] The John W. Cowper Company.

and $8\frac{1}{8}$ ft. high at the center. The side curtains were long enough to reach from the top of this housing and inclose the story below. The canvas roof was put on in the usual way. To fasten down the roof, lines were thrown over it completely across the building and tightened by twisters. All concrete was poured under this roof. Oil-burning salamanders on the floor below kept the temperature at 70°. While this full housing was rather more costly than the usual construction it saved its cost in keeping forms and steel from snow and ice and keeping the men warm at their work. Outside temperatures ranged from 10 to 20°.

In place of slab housing, or to replace it after 48 hours, insulating coverings have been used. On a 60 × 84 ft. building with four floors in St. Paul, Minn.,[1] a floor was poured in a day's run. The story below was inclosed and kept warm by salamanders and camp stoves. As fast as the slab was screeded it was covered with tar paper and a heavy layer of packing hay. This covering and the heat beneath kept the slab from freezing. In building the second story deck of the Wacker drive in Chicago, in parts hay packing of the underslab form and a hay covering on top kept the concrete put in at 65 to 70° at this temperature for a week. In a warehouse operation in Montreal, both an insulating covering and calcium chloride were called in to supplement the canvas enclosure, as described in Sec. 102.

101. Heating Plant and Practice.—In heating canvas enclosures, there is very little variation in practice. Salamanders are most used. Most commonly they are the ordinary coke-burning fire pots but oil-burning salamanders are coming into favor. The ordinary salamander is simply a steel cylinder on legs with openings at the bottom for draft in which a coke fire is kept. With coke burners, the firing has to be watched. The best results are secured with a minimum of smoke and a maximum of heat by putting on frequent small amounts of fuel. Keeping the coke dry will also decrease fumes. Fire hazard has been considered in Chap. III.

[1] Wm. Murphy & Son.

Oil-burning salamanders are of several makes. Figure 64 shows the Hauck salamander. Its overall height is 40 in. The cylinder is 29 in. in diameter and 18 in. high. The burner unit oil tank and connections are the regular

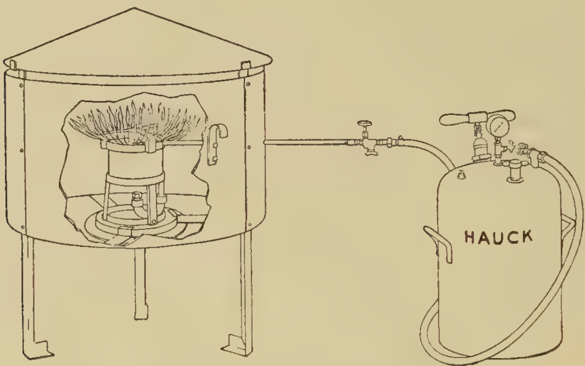


Fig. 64.—Hauck oil-burning salamander.

products of the Hauck company; the tanks may be had in 12-, 15-, and 20-gal. capacities. The oil consumption is given by the manufacturer as 2 gal. an hour. Another

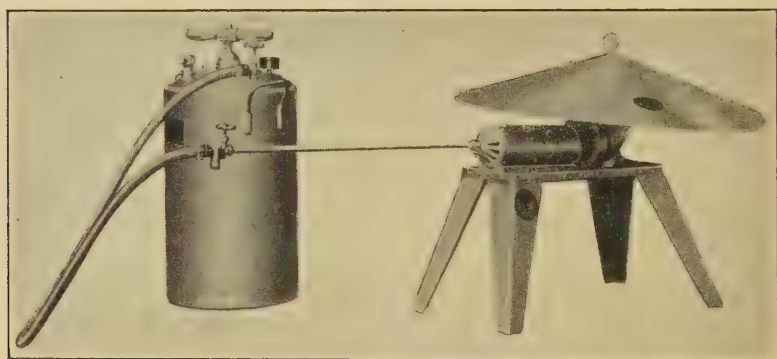


Fig. 65.—Oil burning salamander.

salamander which burns kerosene on light furnace oil is shown by Fig. 65. The makers claim a fuel consumption of ½ to ¾ gal. per hour and a heating capacity of four coke-burning salamanders.

102. Representative Example.—The Montreal Rail and Water Terminals warehouse is a ten-story reinforced-concrete building with about 600,000 sq. ft. of floor space. The contract for this building was signed Sept. 16, 1926, and occupancy of half the building was required June 1, 1927. This made it necessary to pour concrete without interruption all through the winter. The half of the building which was required on June 1 was rushed so that the roof was poured on Jan. 28, 1927. The area of this section was about 25,000 sq. ft. on each floor. About 12,000 cu. yd. of concrete were poured under very severe weather conditions. The thermometer ranged from freezing to 15° below zero during December and January.

The material was sand and crushed stone, separate. It was trucked to the job cold and delivered by means of a ramp running over the tops of bins with hopper bottoms. These bins were lined with steam coils connected up with a 80-hp. vertical boiler and batteries of steam jets were located where they could be turned on when the material was running fast or the weather particularly cold. With this arrangement it was found possible to pour 600 cu. yd. a day with aggregate delivered cold and produce concrete heated to at least 70°. The measuring barrel for mixing water was equipped with steam jets which heated the water to at least 70°.

Calcium chloride was used in the proportion of 2 lb. to each sack of cement. This chloride was received in crystals in bags, and was stored on the first floor of the building above the concrete plant, where a battery of three barrels was used for dissolving the crystals. A steam jet in each barrel was necessary to make the crystals dissolve rapidly. This concentrated solution of calcium chloride was piped to the measuring barrel at the mixer.

The area of slab being poured was closed in with canvas. When the floor slab and column forms were erected, the wall area below the floor to be poured was closed in with canvas and salamanders burning coke, one for every 300 sq. ft. of slab, were set in place under the slab

forms a few hours before starting to pour concrete. Within one hour after an area of slab was poured, canvas covers were placed over the top of it. These canvasses were supported on a frame work of 3 × 4's about $2\frac{1}{2}$ ft. centers resting on 4 × 6's which were supported by the column bars, leaving an air space above the concrete slab about 24 in. high. Openings in the forms and concrete were located about 10 ft. on centers in each direction. These were made of wood 6 in. square on the bottom and 8 in. square on the top. Through these openings the hot air from the salamanders below heated the space between the top of the green concrete and the canvas protection 24 in. above it so that the temperature of the concrete for the first 36 hours was never less than 72°.

Usually these salamanders and the canvas were left in place 48 hours or until necessary to start work on the floor above. The canvas protection was then removed and the salamanders were reduced by half, the canvas enclosure on the walls remaining in place and sufficient salamanders being left under the floor slab to maintain a temperature of 48° for 3 weeks from the date the concrete was poured. The top of the slab was protected by about 8 in. of straw after the canvas was removed.

Removal of forms was started 48 hours after concrete was poured. A 6 × 6 in. permanent shore was placed in the center of each bay. These were not disturbed while stripping. Then 4 × 4 in. shores were placed in the corner of each drop panel as soon as the drop panel was removed. One additional 4 × 4 in. shore was placed halfway between columns, and all these reshores were kept in place until 28 days after the slab was poured. After 42 days had elapsed the 6 × 6 in. permanent shore was replaced by one 4 × 4 in. which remained in place, until 56 days had elapsed. All beams were reshored by 4 × 4's, 5 ft. on centers, for 56 days.

The curtain walls had to be poured at a temperature between 0 and 20°. The outside of the curtain-wall forms were protected by nailing sheeting on the outside of the 2 × 4 studs and packing between the form and this sheeting

with straw. While the wall was being poured a canvas was spread over the top of the wall and salamanders placed on the inside. The area of the section of the building which was rushed through the winter weather was approximately 25,000 sq. ft., each floor of this section containing 825 yd. of concrete. One floor was poured every 8 days, and to do this with the above method, sufficient canvas was necessary to completely enclose three stories. This required 90,000 sq. ft. of canvas and 220 salamanders.

No concrete was poured unless the temperature at eight o'clock in the morning was above plus 10°. With the temperature at 12° below zero and a heavy wind blowing, tests were made inside the weather protection showing that at the edge of the newly poured concrete on the windward side of the building, the temperature was between 55 and 65°. A short distance away from the edge, the temperature was always about 72°. It was found that in order to maintain a temperature of 80 to 90° under the bottom of the slab with an outside temperature of 10 to 20° and a moderate breeze blowing, one salamander was required to each 300 sq. ft. of floor. In order to maintain a temperature of about 40° after the concrete had gotten its initial set, it was found that one salamander was required for about 600 sq. ft. of floor space, but that more of these salamanders had to be located near the outside of the building, and most of them on the windward side.

The following quantities of material were used up to Feb. 23, 1927: 220 tons of coal in the boilers, 590 tons of coke in the salamanders, 139,000 lb. of calcium chloride, 90,000 sq. ft. of canvas, and 220 salamanders.

No concrete was frozen. Progress was at the rate of one floor every 8 days. The quality of the work is as good as work done in summer weather. Unit costs of the work was less than the unit costs on a similar job performed the previous summer, provided the cost of winter-weather protection is disregarded. It costs considerably more to build this work in the winter than in the summer because, with the winter-weather protection costs added, the unit costs were

higher, and there was a further additional expense of about 8 cts. per square foot for putting on a 1-in. floor finish the following summer instead of putting on a monolithic floor finish, which could have been done if the work had progressed in warm weather.

Tests were made during cold weather for the purpose of finding out how much the use of 2 per cent calcium chloride delayed the freezing of concrete. These tests did not take into account the effect of calcium chloride for making the cement set quicker. The results of these tests show that the freezing of the concrete was delayed at least 1 hour when the temperature was 100° above zero. The freezing of concrete was delayed about half an hour when the temperature was about zero and it had very little effect on the time of freezing when the temperature was 10° below zero. The results of these tests show that if 2 per cent calcium chloride is used, the concrete will not start freezing until 1 hour after it is poured, even though the materials are cold.[1]

103. Stripping Forms and Reshoring.—Because the concrete gains strength more slowly at low temperature, more care has to be taken in removing forms and reshoring beams and slabs. The protection described seldom exceeds 5 days in actual practice. The concrete then is still weak and, being exposed to cold, it does not quickly gain strength. Safe practice in stripping forms and reshoring is given in the preceding sections but no set rules should be followed invariably. Form removal and reshoring are operations that call for the superintendent's judgment at any time and in winter this judgment has to be exercised to the utmost. Many disastrous failures of winter concrete construction have been due to too early removal of forms.

104. Steel-frame Buildings.—In steel-frame buildings, protection is required for concrete floors and for certain wall construction. Virtually the same procedure is followed as in concrete buildings. A recommended practice is to place in advance the forms for the floor next above the floor

[1] Parklap Construction Company.

being concreted, supporting them temporarily by hanging them from the steel floor beams. This gives a roof over the floor being concreted. Then curtains are hung from the floor above the one being poured to the floor already poured below. The inclosure is then heated as described for all concrete buildings. When the floor being concreted has set, shores are erected to hold the temporarily wired forms.[1]

Generally, the wall construction—brick, tile, stone—follows after the frame and floor construction and is independently housed. The enclosure is heated by salamanders or electric reflector heaters which are shifted to suit the work. Ordinarily the heating is more for the comfort of the workmen than to protect the work.

105. Draw-form Protection.—In concreting grain bins, tanks, and similar structures where draw forms are used, fairly simple methods of protection and heating have been developed. Figure 66 shows an arrangement employed on a number of operations.[2] A framework covered with tar paper attached to the draw form provides inclosure and a finisher's scaffold as shown. Salamanders set around the scaffold provide heat. A similar arrangement of false framework erected on the working platform attached to the draw form and inclosed by canvas curtains was used in constructing cement

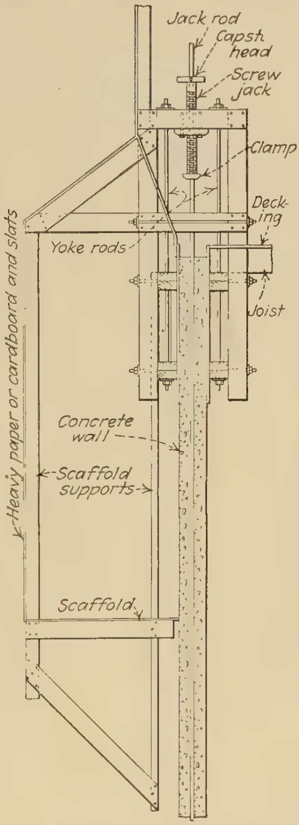


Fig. 66. Protection for draw form concreting.

[1] Henry Ericsson Company.
[2] Horner & Wyatt, Kansas City.

storage bins at Akron, N. Y.[1] Here the forms were heated by two rings of 2-in. steam pipe. Also on the bin bottom inside were set eight Hauck oil burners. The bins

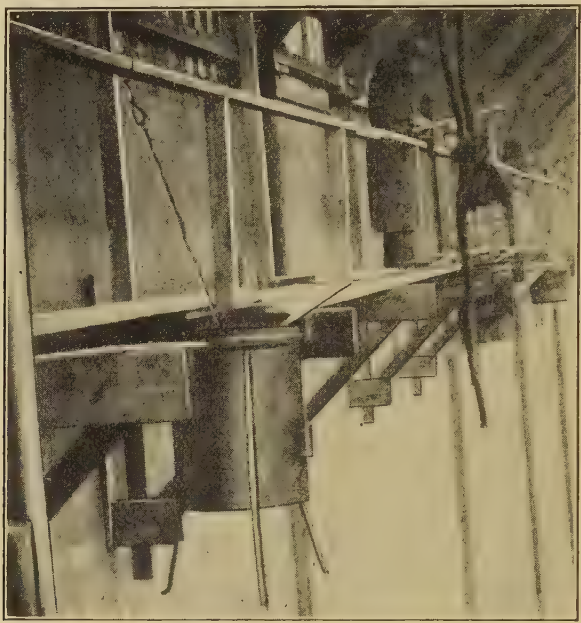


Fig. 67.—Salamander for heating draw form.

were 60 ft. high and 36 ft. in diameter. Figure 67 shows the arrangement of salamanders for heating draw forms in building construction at Cleveland, Ohio.[2]

[1] The John W. Cooper Company, Buffalo.
[2] E. W. Sproul Construction Company, Chicago, Ill.

CHAPTER XV

WINTER BUILDING USING COMPLETE ENCLOSURE

Complete enclosure of the structure being built by a wooden housing has been employed occasionally for reinforced-concrete buildings but chiefly for steel-frame buildings with brick or stone masonry walls and concrete floors. Generally one or both of two conditions have led to its use: (1) unusually rigorous winter conditions, and (2) necessity of full completion without possible doubt for early spring use. These characteristics are brought out particularly in the examples selected to display practice.

106. Lake Placid Club.—One of the earlier of well-planned complete housing operations was the building of the Lake Placid clubhouse in northern New York state in 1922–1923. The building had a reinforced-concrete frame, lower walls of cut stone, and upper walls of brick. The usual temperature of the locality in winter is zero and often the thermometer goes to 20° below zero. The winds are heavy and persistent. Completion by early spring was required. There had to be provided working conditions under which masons, plumbers, and interior finishers could work as well as the concrete workers. The housing was built 5 ft. larger than the building laterally and high enough for its roof to span over the completed building roof. The roof trusses were carried on bents to the full height of the walls. These bents were spaced 10 ft. on centers and were built of 3 × 4 in. posts braced two ways. The exterior walls were 2 × 6 in. studs spaced 30 in. sheathed outside with $\frac{7}{8}$-in. matched boards and inside with tar paper. The temporary housing was self-supporting. It was heated by a vento blower system having a capacity of 15,000 cu. ft. a minute at 150°. Wooden ducts distributed

the hot air. The existing clubhouse boilers supplied steam at a fuel expense of 3½ tons a day. The average inside temperature was 55° with the thermometer going down to −20 to −35°. About 150,000 ft. b.m. of lumber was required.[1]

107. Russell-Miller Mills.—As furnishing some temperature records the Russell-Miller mill at Buffalo, N. Y.[2] is interesting. The enclosed structure was 50 × 183 ft. and eight stories. A part of the enclosure were brick walls of an old building and part was sheathing on building paper on studding. About 40,000 sq. ft. of radiation in steam coils was provided. At days on which floors were concreted the temperatures were:

Date	Outside		Inside	
	A.M.	P.M.	A.M.	P.M.
Jan. 12	31	24	..	46
Jan. 18	32	13	52	64
Jan. 29	41	23	57	52
Feb. 5	39	21	54	52
Feb. 13	15	8	46	45
Feb. 26	29	11	37	40
March 5	34	30		

108. Philadelphia Pier Shed.—An even lighter housing was employed in pier-shed construction in Philadelphia. The shed was two stories and 75 × 500 ft. The roof was on and the brick side walls and concrete floor had to be placed. Studs 3 × 6 in. were erected on the guard logs of the pier and were covered with 20-oz. waterproof canvas lapped at the wall tops over onto the shed roof and fastened. Between canvas shell and shed walls was a 4-ft. space in which radiators were set. The heating plant consisted of four sections, each carrying about 1,250 ft. of radiation. Each section was connected to an 80-hp. boiler at 5 lb., and all were so valved that heat could be concentrated in any section as wind and cold made it necessary. There was

[1] Turner Construction Company.
[2] The John W. Cowper Company.

about 1 sq. ft. of radiation to 300 cu. ft. of space. The temperature ranged from 30 to 45°. About 3½ tons of coal per day were burned.[1]

109. Rest House, Niagara Falls.—A particularly careful study of complete housing was made in building the rest house and station at Niagara Falls, Ont.

The building had to be erected during the winter so as to be ready for the tourists of the spring and summer of 1928. Its location is directly over the Niagara Falls. Thus, the work was subjected not only to the usual rigors of Canadian winter but the spray from the cataract with the wind in a certain quarter was almost equivalent to immersion. The building was of rock-faced stone throughout—the structural design steel with the usual reinforced-concrete floors and concrete fireproofing.

The entire outside scaffolding was erected—in skeleton *i.e.*, the bents of 4 × 4 in. verticals at 8-ft. centers with the ledges. The outside of this timbering was then utilized as the framework for enclosing sheeted walls. While this work, which afforded a fair measure of protection from the spray, was being done, the structural steel was erected. The wood roof of the temporary enclosing shell was then blocked up from the permanent steel roof so that about a 4-ft. space was provided. Extensions were made to include the two towers, the elevator cage shaft, working space and, what was very important, hoarding space for materials. It should be borne in mind that as the ice accumulated in December, January, and February, this work was more or less isolated. Materials to last for weeks at a time had to be laid in when opportunity offered.

The 400,000-cu. ft. contents of the temporary shell was heated by a blower heating plant capable of handling 20,000 ft. of air per minute. The vento sections and the fan and housing were rented from one of the Canadian manufacturers for a nominal figure for 4 months. The high-pressure boiler and motor were available from the contractor's plant. Temperature was maintained at

[1] J. S. Rogers Company, Philadelphia.

approximately 60° without any difficulty. The blower was turned on for a 20-min. period not more than five or six times a day during the coldest weather.

The building was completed under this enclosure in every particular. The copper roof being applied in sections by removing and shifting the blocking. Light was obtained from the lantern which was carried along each side, and as short days and accumulation of ice interfered, artificial light was obtained from three 1,000-watt search lights and the usual small extensions.

The walls and roof of the enclosure were covered with three-ply ready roofing. Ice accumulated from time to time under certain extreme conditions, but never got beyond control as the heat in the temporary enclosure always effected "slides" before the weight became too dangerous.

The labor cost on the temporary enclosure was $2,100. The lumber used, including the scaffold uprights and ledgers but not including planks, of course, was approximately 75,000 ft. b.m. The salvage was most complete. The sheeting (the hardest item to salvage, as a rule) was cleaned and built into panels 3 × 2 ft. and sent to another operation to be used as reinforced-concrete slab forms. Not over 10 per cent was lost. All the 4 × 4 in. stuff was salvaged without difficulty and about 50 per cent of the ledgers. A conservative safe allowance for loss in material under unfavorable conditions would be 20 per cent, in this case $650. The loss of roofing material was 100 per cent or $511.60.

The summary cost of the temporary enclosure was as follows:

Labor	$2,100
Lumber	650
Roofing	512
Miscellaneous	300
Total	$3,562

The cost of operating the heating system was as follows:

Cost of setting up and taking down	$ 179.05
Cost of operation	395.05
Rental charges on blower	400.00
Plant—not including contractor's own equipment of boiler and motor	150.00
Allowance for boiler and motor—coal used—54 tons	418.50
Total	$1,506.60

The total cost of winter protection then was about $5,000 on a $240,000 building.[1]

110. Canadian Pacific Hotels.—In rebuilding or adding to its hotels at Lake Louise and at Banff Springs, the Canadian Pacific Railway has done the work in winter so as to have the structures finished for the summer tourist patronage. It specified timber housing in both cases as follows:

The building operations will be protected from the weather by means of a wooden housing which will completely enclose the whole building. This housing will be built 5 ft. outside the building line, and will be constructed of a framework of wooden studs and sheeting.

The studs will be placed at 33-in. centers, and will be of 2 × 8 in. stock in the lower panels, and 2 × 6 in. stock in the top three stories of the building.

The studs shall be capped, strutted and braced to the steel frame on each floor, and the capping shall be of the same dimensions as the studs on which they are carried.

The sheeting shall cover the whole exterior face of the housing, and shall be built up of ⅞ in. spruce lumber (T. & G. material is not essential).

Roofing paper of heavy and approved quality shall be used as a covering for the whole exterior of the housing. It shall be well secured to the sheeting by means of wood cleats and nails, and all joints in the roofing paper shall be well lapped over and secured.

This was later modified to double ⅞-in. sheathing, with tar paper in between, as it was found more desirable and better able to stand the high winds and severe climate, than the paper applied on the outside and cleated in place.

[1] Pigott-Healy Construction Company, Toronto.

Openings exactly opposite location of permanent windows, and about the same size as the windows, shall be left in the framing and covered with light glazed sash, properly hinged at the top sash rail, so that they can be opened out and secured in any position to facilitate ventilation. Any glass broken or removed during construction shall be replaced immediately.

This housing shall be completely roofed over by means of a similar framed and sheeted covering. The studs shall be 2 in. $\times$ 8 in., and struts carried down to steelwork of roof at suitable intervals to support the temporary roofing, shall be used.

To expedite construction, after the floor forms are in place for any floor, the space between the floor forms and the housing shall be roofed in with a similar framework of studs, sheeting, and roofing paper, so that the space below can be suitably heated, and the work of pouring carried on, if necessary, before it is possible to complete the housing to the roof.

When the weather permits, the housing shall be removed with as little damage as possible to the lumber. It shall be hauled and piled in a suitable location as directed by the chief engineer.

The roofing in of any space between the floor forms and the housing shall be raised to a higher level, or removed, when the chief engineer so directs, so as to economize the heat and allow of its better circulation.

Steel-frame construction lends itself most readily to this type of temporary enclosure.[1]

[1] J. W. Orrock, engineer of buildings.

CHAPTER XVI

SUPPLEMENTARY SERVICES IN WINTER CONSTRUCTION

As the contractor regards winter construction, he considers that he can develop his function fully only when materials production, transportation, and other services are effectively coordinated. The chief of these services are contractual—the function of the owner and engineer in facilitating the work of the contractor through uniform contracts and practices; by properly timing contract lettings; by prompt surveys, plans, etc.; by giving full information; by prompt payment. These affairs being adjusted so as to reduce the handicap, the contractor will meet the physical obstacles of materials supply, transportation, and construction with confidence and can guarantee successful winter construction with certainty.

111. Contractual Service.—Uniform contract requirements and construction practices would ease the contractor's task as a winter contractor. This is particularly true where work is of a public nature and as widely extended as is road building. There is variation in the temperature or time when concreting must stop in different states; in some states concrete paving with the engineers' consent and at the contractor's risk is permitted in cold weather while other states absolutely prohibit cold weather operations. Something of the same conditions prevails in other construction but least probably in building because of the general adoption of the standard contract of the American Institute of Architects, now, with some modifications, the standard of the Joint Conference on Standard Construction Contracts. In every instance, these vagaries of opinion and practice discourage the inclination of the contractor toward winter work. Contract requirements and construction practices

uniform within practicable limits constitute a coordinate service considered desirable by the contractor for winter construction.

Timing contract lettings so that the contractor can schedule his work to take advantage of seasonal conditions encourages winter operations. It can be accomplished by study of seasonal labor and price records as they exist already or may be determined by building congresses and contractors' associations. The Hoover Committee report is instructive with examples of such records. Time of letting contracts has another aspect. It should give the contractor an ample period in which thoroughly to organize his forces and plan his operation. An instance is road construction. With the large volume and slender profit, it is necessary for the contractor to have time to select the most economical equipment and plant layout and to do his buying, to start winter stock piling and, perhaps, heavy grading. Studies of working season records by the Bureau of Public Roads, show, taking the country over, irregular and time-wasting practice in prosecuting road work. Studies of time of letting contracts would encourage and aid contractors to correct this condition.

Poor engineering service handicaps the contractor undertaking winter work. This fault takes the forms most commonly of: (1) limited finances for engineering or haste in starting construction imposed upon the engineer by the owner which prevents complete plans in ample detail necessary for the contractor to plan ahead intelligently; (2) changes in plans after construction has begun which disrupt the contractor's schedules and put new and unexpected duties on his plant and organization; (3) tardiness and inaccuracy in surveying and staking out the work, which hamper the contractor in taking advantage of weather conditions and in the ordinary prosecution of work.

In the same category comes lack of information. Specifications are too often vague and incomplete in their description of materials and of conditions likely to be encountered.

Tardy estimates and delayed payments hamper the contractor on a very considerable proportion of his work. Besides correcting this condition, the owner and the engineer can aid the contractor in planning winter work by allowing estimates on accumulated materials.

While all construction at any time is hampered by these adverse practices wherever they prevail, their effect on winter work is greater because it calls for special methods and more exacting direction. A report of the committee on methods of the Associated General Contractors in discussing seasonal construction pertinently says:

> Delays in engineering and architectural offices in approving estimates, furnishing details promptly, making decisions and assuming responsibility therefor should be eliminated or modified by provision for arbitration. The time of the contractor consumed in fighting these paper battles deprives the job of just that much more supervision and prevents the contractor from keeping his shoulder at the wheel of technical supervision.

112. Materials Supply.—The problem of materials supply takes on emphasized importance in winter construction. Under present conditions winter production of virtually all construction materials is curtailed. This is due, in the great majority of cases, to lack of demand but, in some instances, cold weather hampers production. Weather is an important factor in sand and gravel production and an influence in quarrying and brick making. Sand and gravel production from water deposits or washed sand and gravel production is impracticable in winter as a general proposition. Finally, wet sand and gravel cannot be shipped without freezing in the cars. Commonly, for this reason, the railways will not accept wet sand and gravel shipments in winter. In a lesser degree, cold and water affect crushed stone and brick delivery, particularly in shipment by inland streams.

For the most part, if winter consumption warranted the effort, means could be found to provide any construction material, even sand and gravel, for winter work. Indeed,

now, some sand and gravel producers and more crushed-stone plants are putting up summer stock piles for winter delivery. Shelter, heating, and other winter protection methods are practicable in pit and quarry and, in fact, in a few instances are being employed. Under present conditions of only occasional winter construction, the contractor can get readily and in adequate quantity all construction materials. With winter construction becoming general, an improvement in the winter production conditions would be needed.

113. Materials Delivery.—Storm is more likely to interrupt railway service in winter. This places upon the contractor the need of greater storage so that work may not be stopped if, for a few days, rail deliveries should cease. On the other hand, cars are usually more plentiful in winter and traffic is not so congested by other shipments. This is particularly true now when winter operations are only occasional. In general, the contractor can anticipate better average railway deliveries in winter; his difficulties lie, rather, in unloading and job haulage.

Machinery has materially reduced the winter difficulties of unloading. It is, however, a machine job. So, too, is job haulage in winter. Cranes and power unloaders are the effective means of unloading frozen materials and maintaining operations in frost and storm. Haulage in winter with snow and frost to make the roads bad is a task for service railways and good tractor and motor truck equipment. With considerable hauling distances to and about the operation, materials delivery becomes an outstanding winter operation calling for special planning and outfits.

CHAPTER XVII

SPECIFICATIONS FOR WINTER CONSTRUCTION

Specifications for the performance of construction in winter are uncommon. Architects and engineers have commonly gone no further than general requirements that suitable means be taken to protect and safeguard the work. Contractors have frequently urged that more attention be given to this subject and have offered suggestions of items to be covered and, in a few instances, have drafted complete specifications.

In preparing specifications the following requirements are indicated by John G. Ahlers, Barney-Ahlers Construction Corp., New York.

> To obtain good work in winter time, it is necessary to write definite and clear specifications. In specifications for winter construction, one thing must not be forgotten and that is the comfort of the men on the job and the men supervising the work and men visiting the job. A man can do very good work providing he can warm up once in a while and providing he can eat his lunch under shelter. In planning the job, a contractor should provide for such things. In writing specifications or requirements for a winter-construction job, it should be the duty of the engineer to insert a clause whereby the contractor would be required to furnish ample and adequate shanties, with heat and facilities for washing and cleaning up after the men get through with their work.

There are two essentials in a specification for winter-weather construction. The first is that the material be protected, as previously noted so that when ready to place in the structure, it is free from frost. Material must be covered or heated so that when it goes into the work there is no frost in it. The second requirement is that the

product, when of such nature that it must crystallize or set after being put in place, must be protected until dry enough or has sufficient strength so that frost, if it does get in, will not do any further damage.

Another item that should well be covered in the specifications and has been used in practice on concrete in winter construction is to take samples of the concrete as it goes into the work, exposing these samples to conditions identical with those of the structure itself. Within 3, 4, or 5 days these specimens should be sent to a laboratory and broken to show their resistance, so that the condition of the structure is known. This procedure has been followed on many operations in the winter, as much from the interest of removal of forms as from the question of frost in the material. On such a procedure it has been possible to remove forms in 3 days on flat-slab construction in the winter time, where one might have hesitated under the warm weather of the summer. In other words, the temperature of the concrete itself was between 80 or 90°—it was protected under covers and kept at a temperature around 70° or better for 3 days. The specimens broken showed a strength higher, by about 50 per cent, than that required to carry its full dead and live load, so that there was a wide margin for the removal of forms.

Specifications for winter building on a moderate-sized operation under climatic conditions similar to those of New York City have been drafted by the Turner Construction Company. They are as follows:

1. The contractor shall furnish and instal at the building boiler capacity of at least 50 hp. licensed for 80-lb. steam pressure. This boiler capacity shall always be available for the sole purpose of supplying steam for cold-weather protection.

2. All fine and coarse aggregate shall be entirely freed from frost and warmed either by storing in an enclosed space properly heated or if not stored in an enclosed heated space then by piling over perforated steam pipes having a diameter of 1½ in. and spaced about 4 ft. c. to c. or shall be

heated by inserting 1½ in. perforated pointed steam pipes into the pile. The material piles shall be steamed during the day preceding the placing of concrete and while concreting and shall be covered with canvas during the night preceding the placing of concrete.

3. All mining water shall be heated by injecting live steam into the water barrel at the mixer through a pipe at least 1½ in. in diameter.

4. A steam line shall be carried up with the form work and immediately before starting to place concrete all forms and steel reinforcing shall be thoroughly cleaned and warmed by live steam supplied through a steam hose.

5. Before starting to concrete the columns of any story or the floor supported by such columns, the contractor shall hang canvases to enclose the section of the story to be concreted, being careful to maintain an air space between the exterior faces of the concrete and the canvas curtains. Canvas curtains shall be well lapped to exclude wind and shall be large enough to reach well below the surface of the floor supporting the columns which are to be concreted.

6. Before starting to concrete, salamanders containing coke fires shall be placed inside the enclosure at proper intervals to maintain a temperature of about 70° at the under side of the floor slab. This will generally require about one salamander of usual size to each 300 sq. ft. of floor space. One salamander shall be placed near each exterior column unless temperature is below 20°, when two salamanders shall be placed one each side of each exterior column. On windy days use two salamanders at each exterior column on windward side of building.

7. Holes about 8 × 12 in., one to about every 300 sq. ft. shall be formed through the floor slab by cutting holes in the floor form and inserting a wood frame in the concrete, these holes to be made larger at the tip of the slab than at the bottom of the slab in order to hold the concrete which will later be used to fill them. These holes permit hot air to rise into the space between the top of the slab and the canvas covers described in the next paragraph.

8. As rapidly as the floor slab is concreted it shall be covered by canvas covers well lapped and supported about 6 to 18 in. above the surface of the concrete by a framework supported on the wood frames around the heat openings or on the steel reinforcing rods which project above the floor line at columns. These top covers shall be well lapped over the side curtains.

9. Full continuous heat is to be maintained in each section for 110 hours after the concrete is poured, except, should the outside temperature fall below 20° F., the heating shall be continued for 1 day for each day on which the temperature falls below 20° but not to exceed 2 additional days of 24 hours each.

10. When using beam-and-girder construction, top covers shall be kept in place for 48 hours but with flat-slab construction they shall be kept in place for 72 hours, except that top covers may be removed between 8 A.M. and 5 P.M. on days when the temperature is above 35° to permit of setting column forms but shall be replaced at 5 P.M.

Side covers shall remain in place as long as heat is continued, except that after 48 hours the curtains outside of exterior columns may be removed one at a time for only sufficient time to strip the forms from the exterior columns, after which they should be immediately replaced.

The specifications of the Michigan Highway Department for winter bridge construction are given in Chap. IX and the specifications of the Canadian Pacific Railway for winter building are given in Chap. XV.

INDEX

I

J

L

M

N

P

R

S

T

W